Rangitaiki River Stopbanks Assessment

Section 13

Left Bank 10600 to 11200m

Prepared for

Environment Bay of Plenty

August 2006

Contents

1 Introduction

The section of stopbank on the left bank of the Rangitaiki River from 10600m to 11200m was not identified as a possible problem area in a study of the information available on the stopbanks along the river (Rev 1). This was due to there being no recorded significant earthquake damage, the stopbank not being particularly high and there being a broad river berm over most of the length. There is no record of problems developing along this section of stopbank during the 2004 flood, however as most of this stopbank length runs behind a commercial area it is possible that problems were undetected.

Studies carried out on other sections of the stopbank have shown that due to the nature of the local soils there could be problems in the design 100 year return period flood where they would not usually be expected. A decision was therefore made to assess all the stopbanks through Edgecumbe. This report addresses the length of stopbank between previously investigated Section 5 (July 2006) and a length along College Road assessed by Opus International Consultants Ltd in June 2000.

This report presents the following information:

- the results of insitu investigations,
- laboratory grading test results,
- the results of seepage analyses for the 100 year return period flood and
- possible remedial measures.

This report is the property of our client, Environment Bay of Plenty and Ice Geo and Civil. The comments within relate only to the length of stopbank along the Rangitaiki River left bank from 10600m to 11200m.

2 Site Description

Along the length of the study section the stopbank varies in height from 1.9m to 2.5m. In some areas there is a further small fall away from the stopbank toe. The river berm is typically 40 to 50m wide and is at close to the ground level on the inside of the stopbank. The river berm is narrowest at the downstream end of the study section where it is about 15m wide. There is a bench in the river berm at Cross Section 2 (Figure 1 and 4) where the berm has been used as a borrow area.

There is only one private dwelling along this section of the stopbank. The remainder of the land is in Council or commercial ownership. There are some quite large open spaces occupied by car parks, grass and tennis courts. The Cosmopolitan Club and Squash Club buildings are quite close to the stopbank. There is a culvert under the stopbank at Cross Section 3 and a timber pole retaining wall cut into the stopbank at the downstream corner of the tennis court.

3 Subsurface Investigations

The subsurface investigations consisted of 19 hand augers carried out in eight cross sections at roughly 70m intervals along the study length (Figure 1). The location of the hand augers was chosen on the basis of spacing, land owner permission and the presence of underground and overhead services. The hand augers were continued until the holes collapsed below the ground water level or the holes squeezed in. The holes were typically 3.5 to 4.0m deep on the inside of the stopbank and a little shallower on the river berm. The hand auger logs are included in Appendix A.

Opus International Consultants carried out a borehole to 8m depth through the stopbank just downstream from the study section. The soils found in this borehole are consistent with those found at this end of the study section.

The ground surface and subsurface soil layers typically slope gently away from the river in alluvial plains such as the Rangitaiki. Some subsoil layers were found to slope this way but there is also a lot of discontinuity in the soil layers at right angles to the present river bank. There seems to be greater consistency between adjacent cross sections. This is possibly due to this section of stopbank being on the inside of a bend where river braids have cut across to form new channels which are later in-filled with different soils.

The soils are predominantly light pumice based silts and sands with minimal cohesion. Some thin layers with a clay content were found downstream of Cross Section 4. The natural surface layer is a brown fine sandy silt. This is usually underlain by a grey silt or silty fine sand. As along much of the river, pumice lapilli were found at between RL1.3 and 2.1 below the river berm in half of the cross sections. It appears that the lapilli layers dip away from the river as they were not found on the inside of the stopbank even though the hand augers penetrated to deeper levels.

An old rubbish pit was found at Cross Section 6 in HA14. It appeared to extend to 2.5m depth.

The ground water level was found to be at about 3m depth on the inland side of the stopbank in June.

4 Laboratory Test Results

Hydrometer particle grading tests were carried out on four samples from different depths in HA5 to provide information on the permeability of the soil layers (Appendix B). The grading test results are summarised in Table 1. The permeabilities given are estimates based on the Hazen formula:

$$k=0.01d_{10}^2$$

Table 1: Particle Grading Results

Sample	Description	D_{10} (mm)	D_{60} (mm)	permeability
HA5 0.7m	brown sandy silt	0.0015	0.009	2.3×10^{-8} m/s
HA5 0.9m	grey silty fine sand	0.01	0.014	1.0×10^{-6} m/s
HA5 1.5m	grey sandy silt	0.0045	0.052	2.0×10^{-7} m/s
HA5 2.7m	grey silty sand	0.011	0.14	1.2×10^{-6} m/s

These test results have been used in conjunction with the results of other soil tests from along the river to estimate the permeability characteristics of each soil type. Permeability tests on the upper brown silt from nearby sites have shown that Hazen's formula tends to under-estimate the permeability of this soil. A permeability of 2×10^{-7}m/s has therefore been assumed for this layer in the seepage analyses.

5 Analyses

5.1 Discussion

The hand augers carried out provide subsoil profiles in isolated locations only. The hand auger logs show considerable variation in the soil layers and it is possible that in terms of the seepage response to a flood in the river there are worse combinations of soil layers than those identified. One old rubbish pit was discovered during the investigations and it is possible that there are other pits or buried rotten tree stumps along the stopbank. There is also the possibility of undetected buried pipes below the stopbank.

The computer programme used to analyse the seepage problems, Geo-Slope Seep/W (Version 5), is a two dimensional programme. Therefore three dimensional effects, such as lateral changes in the soil profile or the presence of an impermeable surface of given width, can not be accurately modelled. The seepage analyses carried out must therefore be considered indicative only.

The two problems being investigated are heave and piping. The most common remedial measures for heave are the addition of an overlay on the ground surface or the construction of a pressure relief trench (or wells). Over most of the study length the use of an overlay is impractical due to the presence of structures close to the stopbank toe. The aim of the remedial measures is to achieve a minimum factor of safety against heave of 1.1 to 1.2.

The risk of piping can be reduced by increasing the length of the seepage path by the addition of overlays or by installing a drain in the susceptible area to allow seepage without the removal of soil particles. Pressure relief trenches can therefore be used to reduce both the risk of piping and heave. The maximum hydraulic gradient considered acceptable with the light soils in this area is 0.4.

Seepage of only small volumes of water from the ground surface can significantly reduce the uplift pressures on a surface layer with a lower permeability than those underlying it. Seepage from the ground surface inside the stopbank has been allowed where there are no structures on concrete slabs or sealed surfaces such as roads and tennis courts. The build up in water pressure below a sealed surface can lead to high concentrations of flow around the edge of the structure. Loose basecourse behind a kerb may act as a filter which allows concentrated water flow from under a road without letting soil particles escape.

The soil models analysed for each cross section are included in Appendix C.

5.2 Flood Hydrograph

EBoP has provided a 100 year return period flood flow hydrograph for the Rangitaiki River at their benchmark number 27 (Figure 2). This is an eight day hydrograph which rises to a peak of RL6.65 on the third day of the flood. The top of the stopbank along Section 13 is at RL6.9 to 7.0. It therefore appears that the design freeboard for an urban area has not been met. In the 100 year flood the water level stays close to the peak level for two days before beginning to drop. During the July 2004 flood the level was high for less than a day before a rapid drop due to the breach just upstream of the substation, therefore this flood was not a true test of the stopbanks.

5.3 Soil Model

The soil layers found in the hand augers were simplified in the models used for the seepage analyses (Figures 3 to 10). The grading test results were compared to the field descriptions of the soils to confirm the soil category. The surface layers of silt and sandy silt were modelled with the same low permeability. Below this the layers were divided into silty fine sand, fine sand, fine to medium sand, clayey silt and coarse sand and lapilli. The permeabilities assumed were conservatively based on the grading test results for this site and near-by sites previously investigated. In terms of the assessment of heave potential of the upper silt layers it is conservative to assume a permeability on the low side of that found from tests for the silts and on the high side for the more permeable sand layers acting as aquifers.

Table 2 summarises the saturated soil parameters assumed. It was conservatively assumed that there is a thick layer of coarse sand and pumice lapilli below the depth of investigations.

The Geo-Slope Seep/W (Version 5) computer package used for the seepage analyses contains a library of soil grading curves with corresponding hydraulic conductivity and water content versus water pressure relationships. The particle gradings observed on site were compared to those in the Seep library and the closest fit chosen as the soil model to be used in the seepage analysis.

Table 2: Assumed Soil Permeabilities

soil	k_h (m/s)
stopbank fill	2×10^{-6}
brown and grey silt	2×10^{-7}
silty fine sand	4×10^{-6}
silty fine to medium sand	1×10^{-5}
silty fine to coarse sand	5×10^{-5}
fine sand	6×10^{-5}
fine to medium sand	1×10^{-4}
clayey silt	5×10^{-8}
coarse sand and lapilli	5×10^{-4}

There was no apparent evidence of significant banding within most of the layers therefore the horizontal and vertical permeabilities were assumed to be the same for all the soils except the stopbank and the coarse sand and lapilli. The vertical permeability of these soils was assumed to be half the horizontal. In the stopbank this was due to the compaction process. Banding of sands and lapilli and some peat lenses were observed in the investigations penetrating this layer.

The natural soils have been assumed to have a weight of 14kN/m^3. This is conservatively low as the upper brown silts typically have a saturated density of 15.5 to 16.0 kN/m^3. The lower value used should allow for more pumiceous silts near the surface and the rare occasion when the river is in flood due to rain in the upper catchment which has not saturated the lower catchment.

5.4 Cross Section 1

Cross Section 1 is immediately downstream of the highway bridge. The stopbank is about 2m high and the river berm 50m wide. The surface silt on the inland side of the stopbank was found to be 900mm thick. It is underlain by silty fine to medium sand. On the river side of the stopbank are thin layers of clean sand, clayey silt and silt above the silty fine to medium sand.

An initial static seepage analysis was carried out assuming a ground water level of RL2.7 on the inland side of the model and a river level of RL2.5. A transient seepage analysis was then carried out modelling the full eight days of the 100 year flood. A two hour time step was used.

An allowance was made in the soil model for seepage from the ground surface inland from the stopbank.

The transient flood analysis showed that there could be a problem with heave of the upper silt layer up to about the fence 30m away from the inland toe of the stopbank. The hydraulic exit gradient at the toe of the stopbank was also found to be unacceptably high (>0.4).

An overlay 500mm thick extending 30m from the toe and then tapering would be required to provide an adequate factor of safety. This width of overlay will not be possible close to the club buildings.

The modelling of a pressure relief trench down to the medium sand layer at the toe of the stopbank reduced the uplift pressures but not sufficiently to provide a factor of safety against heave of more than 1.2. The addition of a 30m wide, 300mm thick overlay would be required to reduce the uplift risk to an acceptable level. Where there is no room for the overlay a second pressure relief trench 12m from the stopbank toe with a 300mm thick overlay between the trenches would be an acceptable alternative.

The estimated flow from the toe trench is 5 m^3/m length of trench over the eight day flood.

At the upstream end of the study section adjacent to the highway there is a reasonable width of ground between the stopbank and any structures. As there are buried services running parallel to the highway it is suggested that the thick overlay option be used from here until it intersects a private property boundary. The analysis of Cross Section 2 shows a single pressure relief trench is the preferred option there. It is therefore suggested that the option of a toe trench with a thin overlay, and an extra pressure relief trench where required, be used for the rest of this portion of stopbank as shown on Figure 11.

5.5 Cross Section 2

At Cross Section 2 the stopbank is 2.5m high on the inland side. The river berm is at about the same level as the ground on the inland side of the stopbank and is about 40m wide. There is a road on the inside of the stopbank. On the inland side of the stopbank the upper silt layers are from 0.8 to 2.6m thick and are underlain by silty fine to medium sand as found in Cross Section 1. Pumice lapilli were found at 2.3 to 2.5m depth below the river berm. It has been assumed that this lapilli layer extends under the stopbank.

The transient flood analysis showed that parts of the upper silt layer up to 35m from the toe of the stopbank could lift in the 100 year flood. The maximum hydraulic exit gradient is about 0.9. An overlay to improve the factor of safety would need to be 300mm thick. This width of overlay could cause surface drainage problems around the squash club and carpark areas. An alternative is a pressure relief trench to 2.5m depth at the toe of the stopbank. This reduces the hydraulic exit gradient to 0.3. The flow from this trench has been estimated at 25m^3/m length of trench over the eight day flood period.

5.6 Cross Section 3

Cross Section 3 is similar to Cross Section 2 in both geometry and subsoils. HA 7, in the river berm, is adjacent to a culvert outlet. A drain has been cut through the upper river berm silts from the culvert outlet to the river bank.

Therefore this portion of upper silts has not been modelled in the seepage analysis.

The seepage analysis showed that there could be potential for heave of the upper silt layer up to 35m from the inland stopbank toe as for Cross Section 2. High pressures also develop under the lower silt layers. Close to the stopbank toe an overlay about 650mm thick would be required to achieve acceptable factors of safety. The overlay could be a little thinner further out from the toe. This overlay could create drainage problems for the squash club and tennis courts. High pressures will develop under these sealed surfaces.

As for Cross Section 2 an alternative to the overlay is a 2.5m deep pressure relief trench at the toe of the stopbank. This will significantly reduce the uplift pressures under the silt layers and sealed surfaces and bring the hydraulic exit gradient to an acceptable level. The volume of water flowing from the pressure relief trench could be in the order of $60m^3/m$ length of trench over an eight day flood if there is a thick layer of pumice lapilli below the stopbank. This large volume will have to be picked up by the existing pumped stormwater system within the town to prevent surface flooding.

5.7 Cross Section 4

Cross Section 4 passes through the tennis courts. The stopbank is 2.5m high and the river berm about 30m wide. There is about 500mm of sandy fill on the inland side of the stopbank and the upper brown silt is underlain by 1m of clayey silt. High water pressures will develop under this clayey silt layer during a flood. The river berm was found to consist of silty fine sand.

The tennis courts were modelled as an impermeable surface in the seepage analysis. This could be conservative as the drawings for the tennis court construction (Whakatane District Council 1392/4, 1194) show 25mm of AC over 150mm of AP40. It is unlikely that the tack coat below the AC is waterproof and water can probably seep through from underneath.

In the 100 year flood analysis it was found that the pressures under the clayey silt produced factors of safety against heave of just under 1.0 to about 40m from the stopbank toe. There would also be high hydraulic gradients along the edge of the tennis court. If the tennis court lifts and cracks in a 100 year event it is likely that water will escape without the loss of soil fines due to the AP40 acting as a filter. If this cracking is considered acceptable an overlay between the stopbank toe and the tennis court may be all that is required. However the overlay would have to be about 1m thick.

A 3m deep pressure relief trench would reduce the pressures to an acceptable level. The flow from this trench has been estimated at $30m^3/m$ over the eight day flood period assuming a thick layer of lapilli.

It is suggested that investigations be carried out at the edge of the tennis court to see if the AP40 extends beyond the court to act as a filter. If not a strip drain or small trench filled with drainage metal should be installed along the edge of the court.

5.7 Cross Section 5

The geometry of Cross Section 5 is similar to that of Cross Section 4 except that the river berm has a greater slope towards the river. The clean sand layers that were found inside the stopbank at Cross Section 4 are found outside the stopbank at Cross Section 5. This is probably due to the bend in the stopbank and the braiding effect discussed above.

Close to this cross section the timber pole retaining wall is built into the side of the stopbank. The analysis therefore assumed a vertical face on the inland side of the stopbank. The wall has drainage metal and geotextile behind it so piping due to high hydraulic exit gradients is not expected to be a problem. The poles, which up to 1.7m deep, have been concreted in therefore there should be no seepage paths up the sides of the poles.

The analysis of the 100 year flood with seepage allowed from the ground surface showed there is potential for heave of the upper silt layer to about 10m from the stopbank toe and there is potential for deep seated heave of the lower silt layers to about 25m from the stopbank toe.

A pressure relief trench about 2.5m deep will decrease the uplift pressures to acceptable levels whether or not the sealed tennis court is allowed for. The trench will have to be installed away from the wall foundations to prevent the wall rotating during construction. The flow from this trench has been estimated at about $35m^3/m$ length of trench assuming the pumice lapilli found in HA11 extends under the stopbank.

5.8 Cross Section 6

The ground on the inside of the stopbank at Cross Section 5 has been built up resulting in a stopbank height of about 2.0m. The subsoils at the site are confused by the presence of a rubbish pit at the inland toe which appears to have resulted in disturbed soil to 2.5m depth (HA14). There is only about 300mm of brown silt over this area. A pressure relief trench at the toe of the stopbank is required upstream and downstream of this site therefore it is considered that the rubbish pit should be excavated and replaced with compacted silty material and a pressure relief trench installed here as well.

5.9 Cross Section 7

The stopbank at Cross Section 7 is 2.0m high but there is a further 1m fall to College Road. The upper layers of soil appear to have been removed from the river berm. On the inland side of the stopbank there are layers of silt, silty fine sand and clayey silt.

In the 100 year flood analysis high water pressures develop under the upper and lower silt layers. An overlay would have to be over 1m thick to provide an adequate factor of safety against heave. A pressure relief trench at the toe of

the stopbank does not quite reduce the pressure near the road sufficiently. A second pressure relief trench or strip drain at least 1m deep is suggested behind the kerb. The flow from these trenches could be as much as 60m^3/m over an eight day flood.

5.10 Cross Section 8

Cross Section 8 is similar to Cross Section 7 in geometry and subsoils except that the road is closer to the toe of the stopbank. As for Cross Section 7 high pressures develop under the silt layers whether it is assumed there is a thick lapilli layer under the stopbank or a thick layer of silty sand. A pressure relief trench about 3m deep reduces the pressures to an acceptable level. The maximum hydraulic exit gradients are less than 0.1 with the pressure relief trench. This trench should be extended to join in with the toes drains installed along the flood wall downstream. Care will be needed to avoid under ground services. The flow from the trench could be as much as 80m^3/m over the eight day period if there is a lapilli layer.

6 Conclusions

1. Extensive remedial trenches in the form of pressure relief trenches and / or overlays are required along the whole length of stopbank LB 10600 to 11200m (Figure 11).

2. The freeboard for the design 100 year flood should be checked along the stopbank.

3. The recommended pressure relief trenches could produce large volumes of water over a significant flood. A check should be made to see that the town's stormwater system can take the increased flow.

4. An old rubbish pit was found at Cross Section 6. This should be dug out and replaced with compacted silty soil.

5. The excavation of the pressure relief trenches should be supervised to ensure the highly permeable soil layers are reached.

6. Investigations should be carried out along the edge of the tennis courts and squash club building to see if further pressure relief is required.

M. O'Halloran 13 August 2006
BE, PhD, Dip BA, MIPENZ (Geotechnical), CPEng IntPE

References

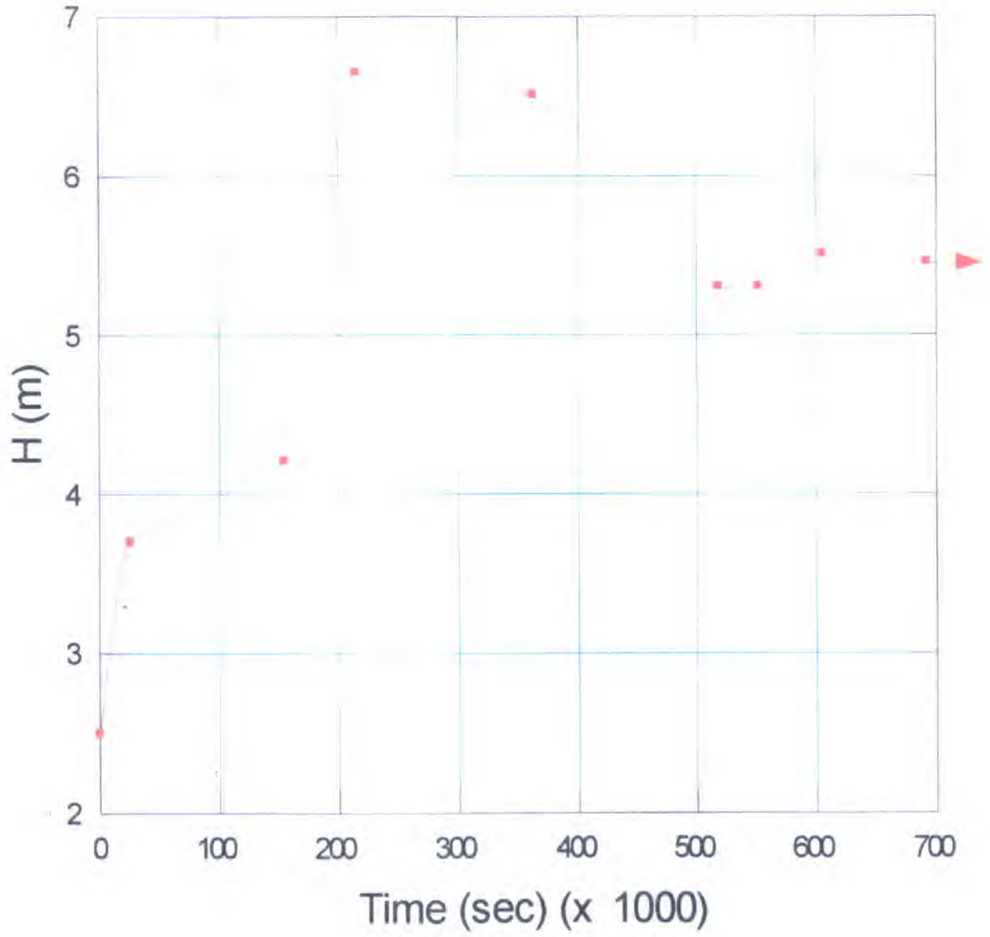
1 Ice Geo & Civil (Sept. 2005) Rangitaiki River stopbanks, review of stability.

2 Opus International Consultants Ltd (2000) Stopbank assessment Rangitaiki River, Edgecumbe. Geotechnical Report No. 2069.

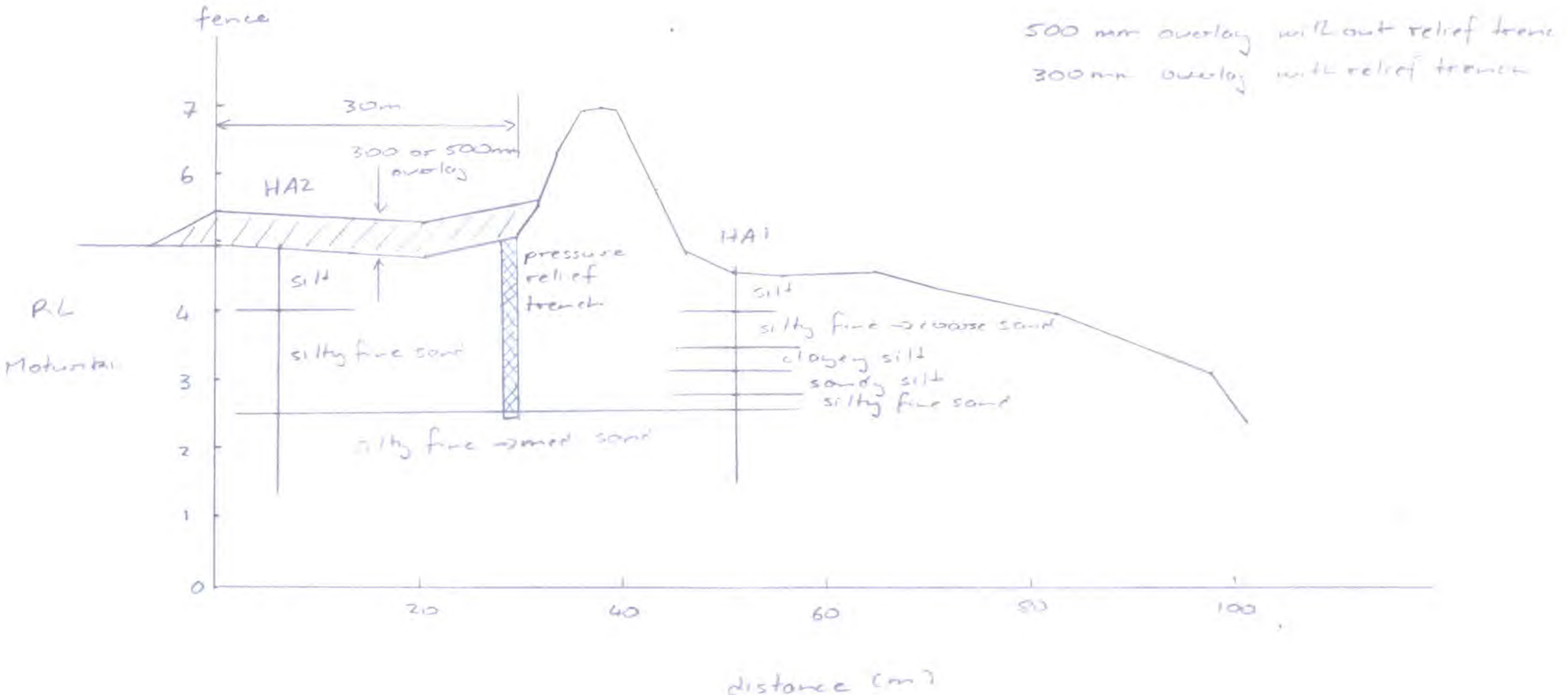
Plan

Rangitaiki River Stopbank
LB 10600 to 11200m

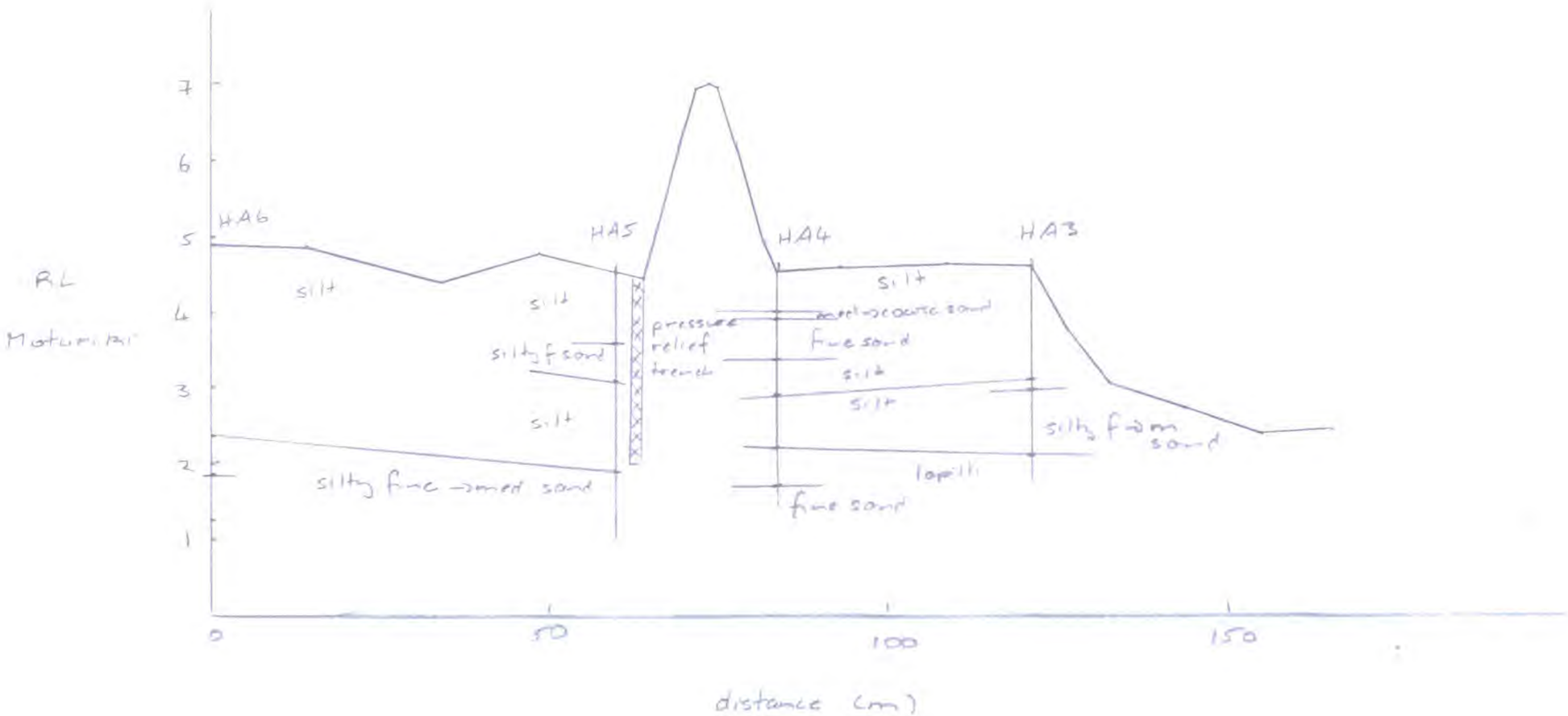
Figure 1



100 year flood flow hydrograph



Cross Section 1

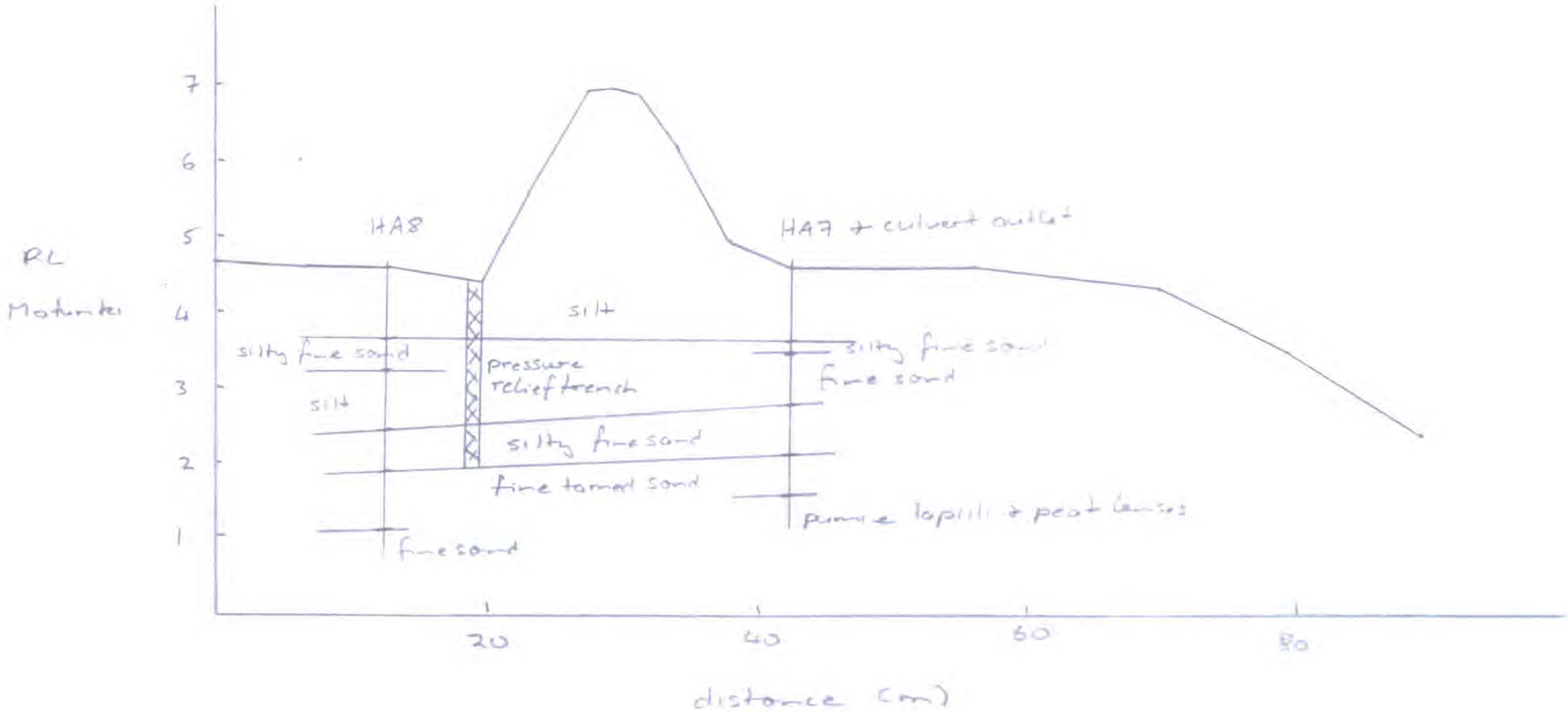


ICE GEO & CIVIL

Cross Section 2

Rangitaiki River Stopbank
LB 10600 to 11200m

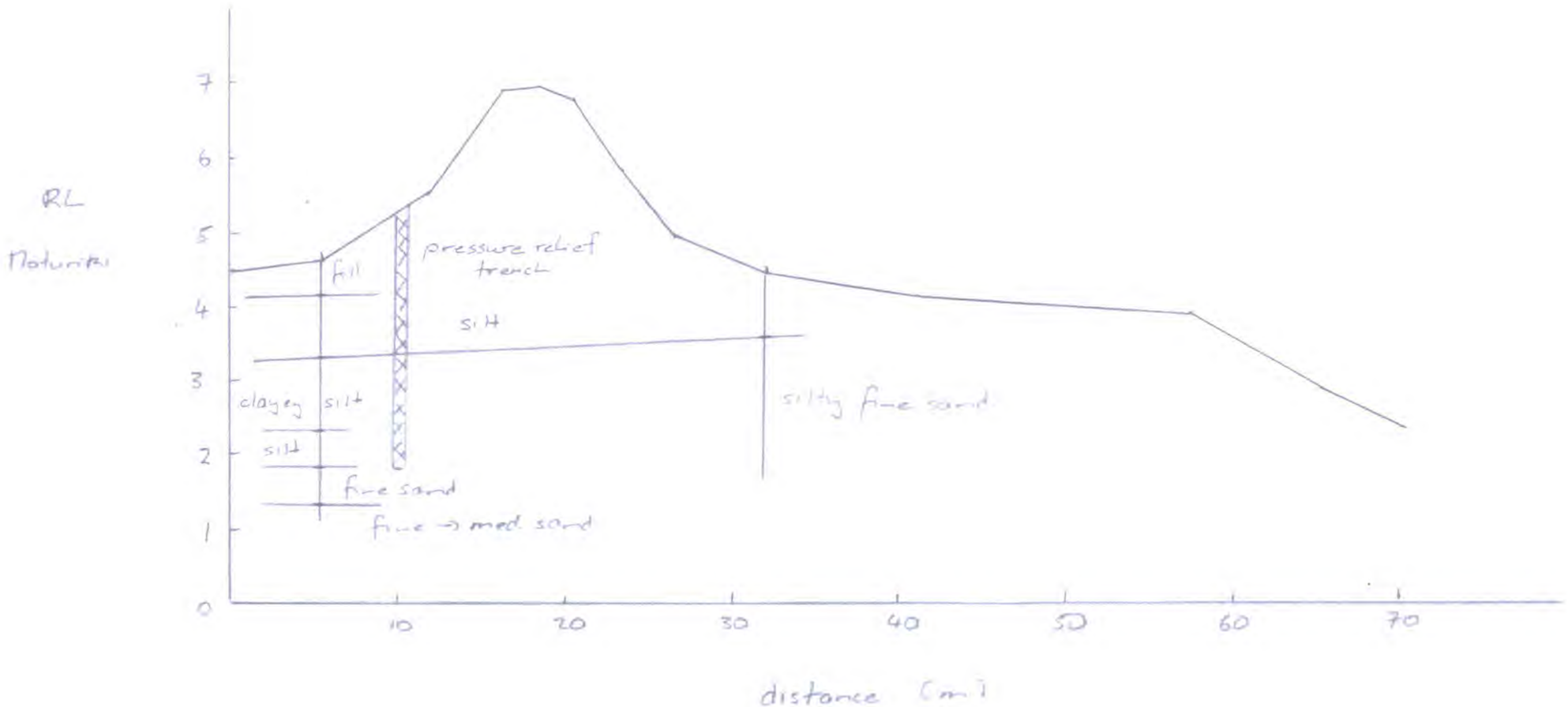
Figure 4



Cross Section 3

Rangitaiki River Stopbank
LB 10600 to 11200m

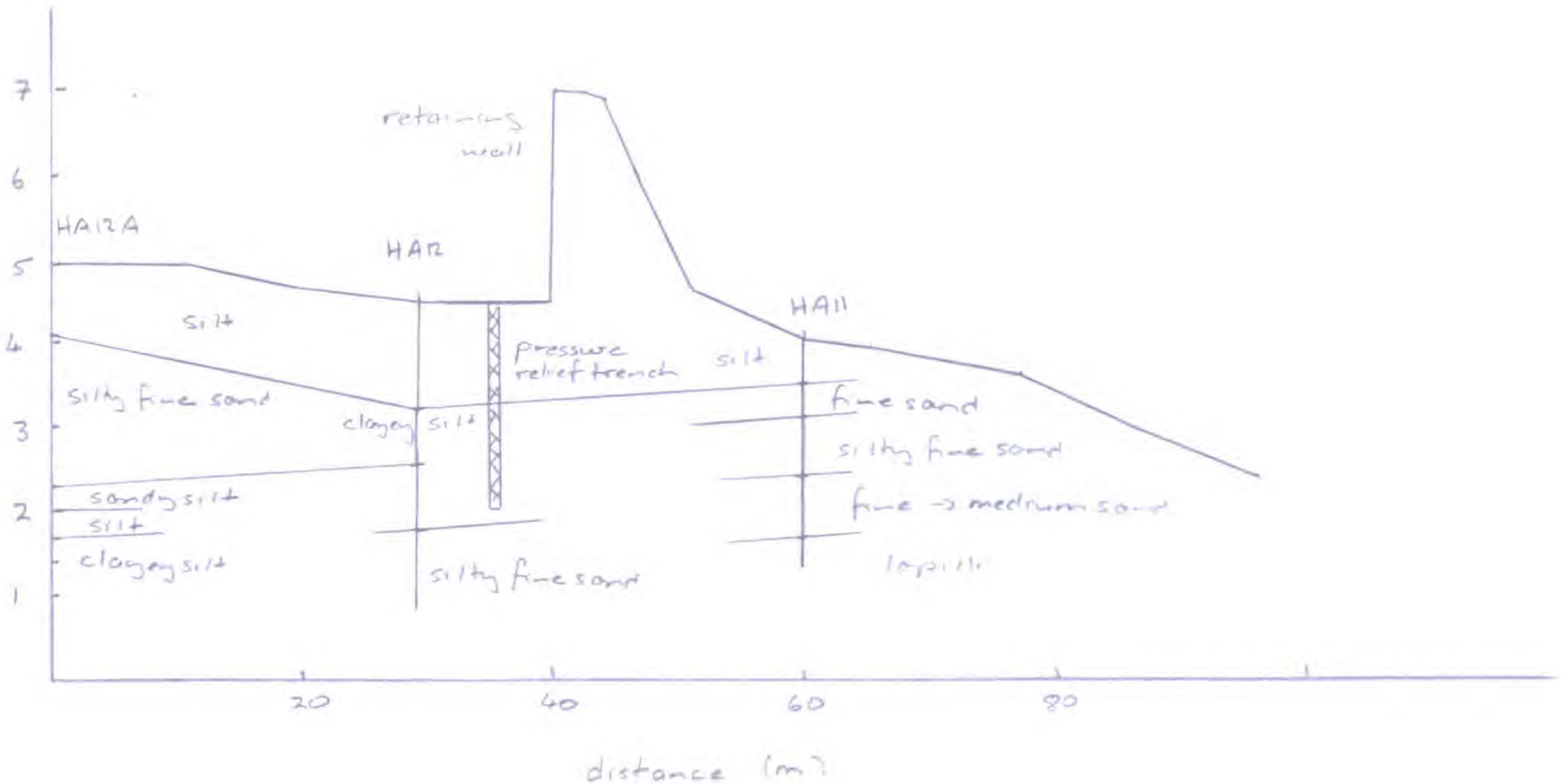
Figure 5



Cross Section 4

Rangitaiki River Stopbank
LB 10600 to 11200m

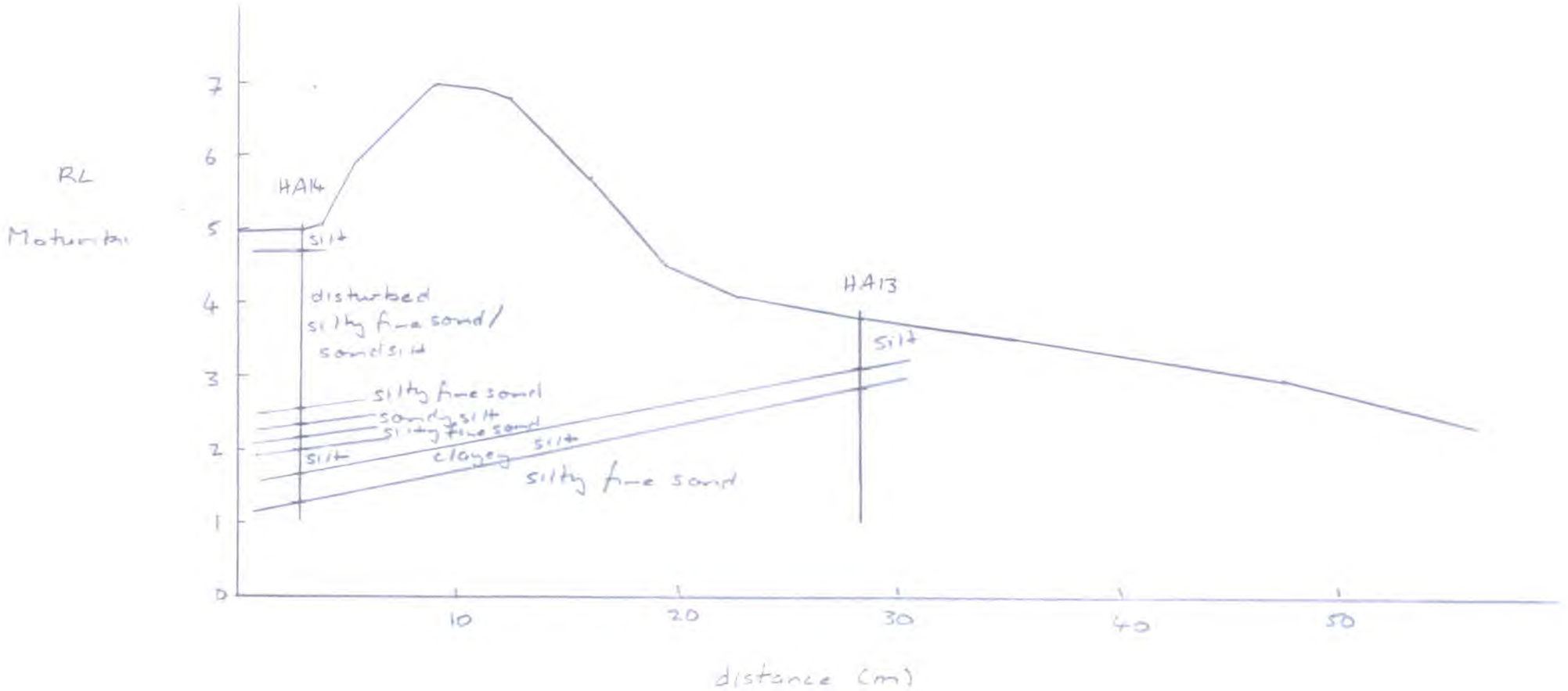
Figure 6



Cross Section 5

Rangitaiki River Stopbank
LB 10600 to 11200m

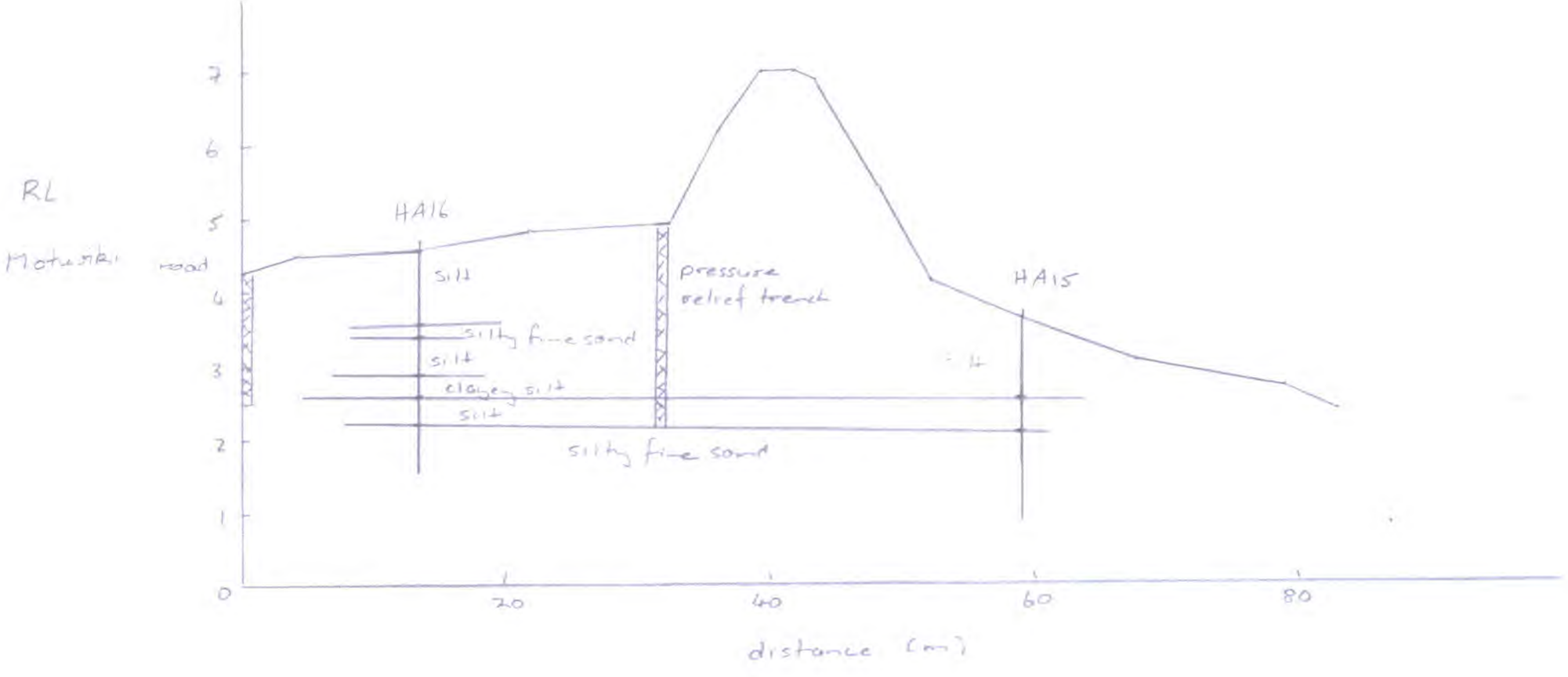
Figure 7



Cross Section 6

Rangitaiki River Stopbank
LB 10600 to 11200m

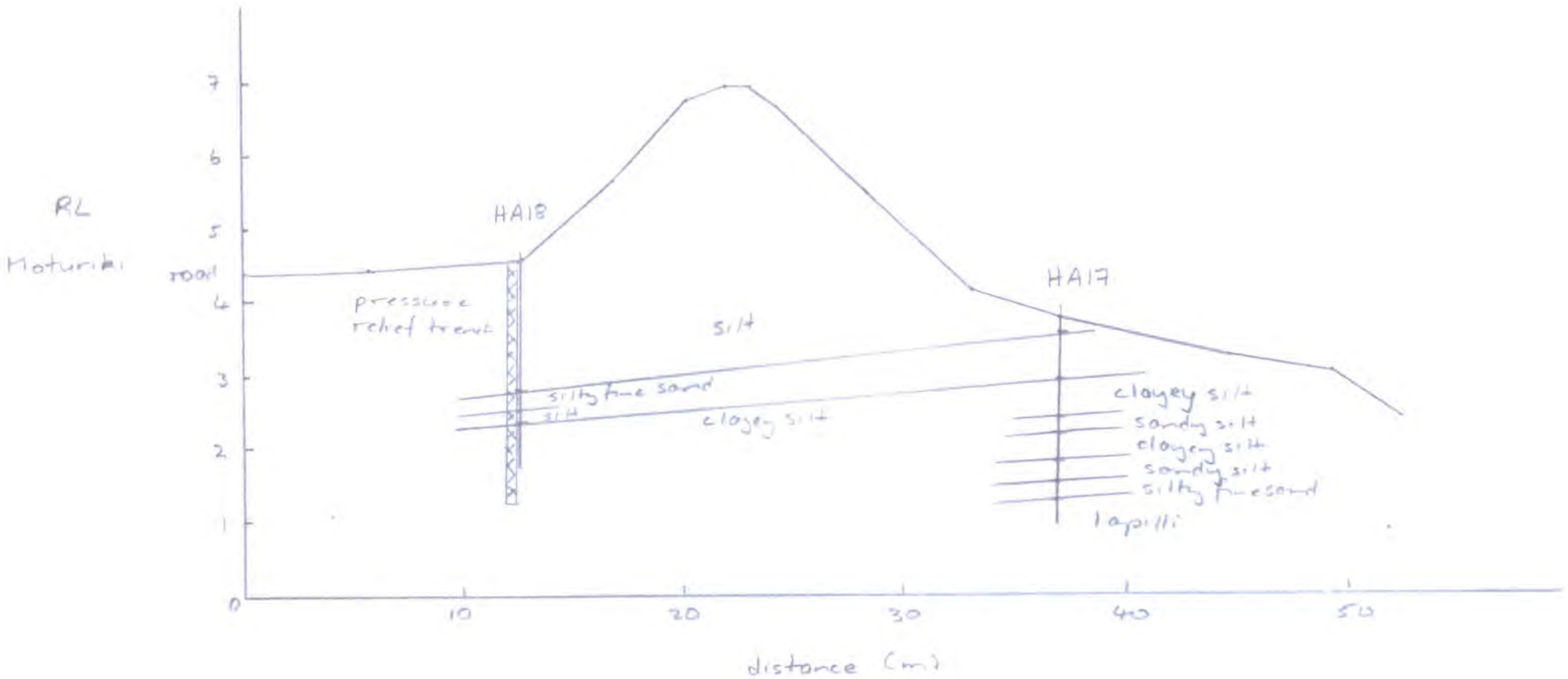
Figure 8



Cross Section 7

Rangitaiki River Stopbank
LB 10600 to 11200m

Figure 9



Cross Section 8

Rangitaiki River Stopbank
LB 10600 to 11200m

Figure 10

Remedial measures

Rangitaiki River Stopbank
LB 10600 to 11200m

Figure 11a


HA17
HA18
strip drain
HA15
HA16
pressure relief trench
HA13
HA14
HA11
HA12A
HA12
HA9
HA10

Appendix A

Hand Auger Logs

ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

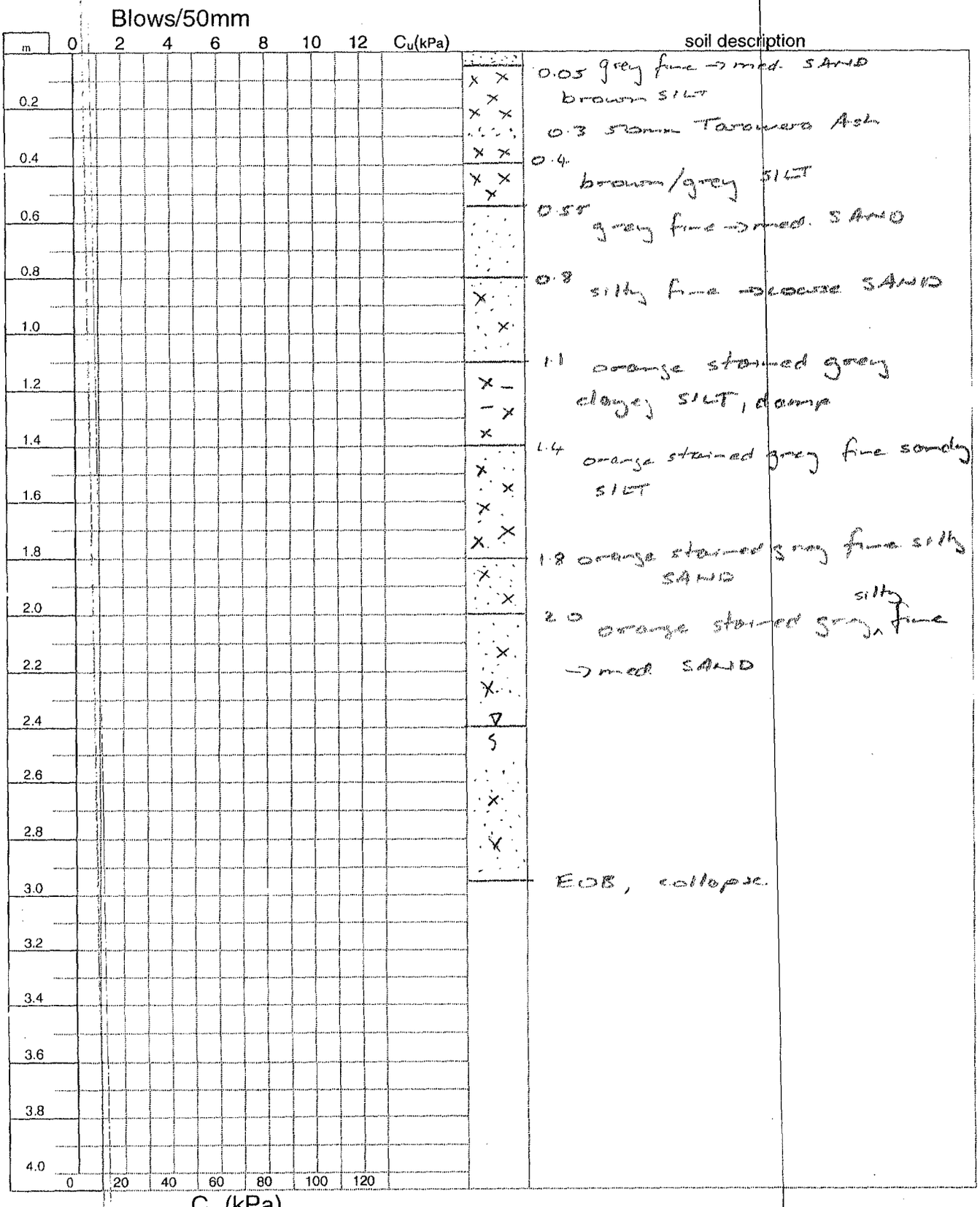
Hand Auger Log

Test Number: HA1

Job Name: Rangitaiki Stopbank Section 13

Date: 26/6/06

Tested by: M.O'M



ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

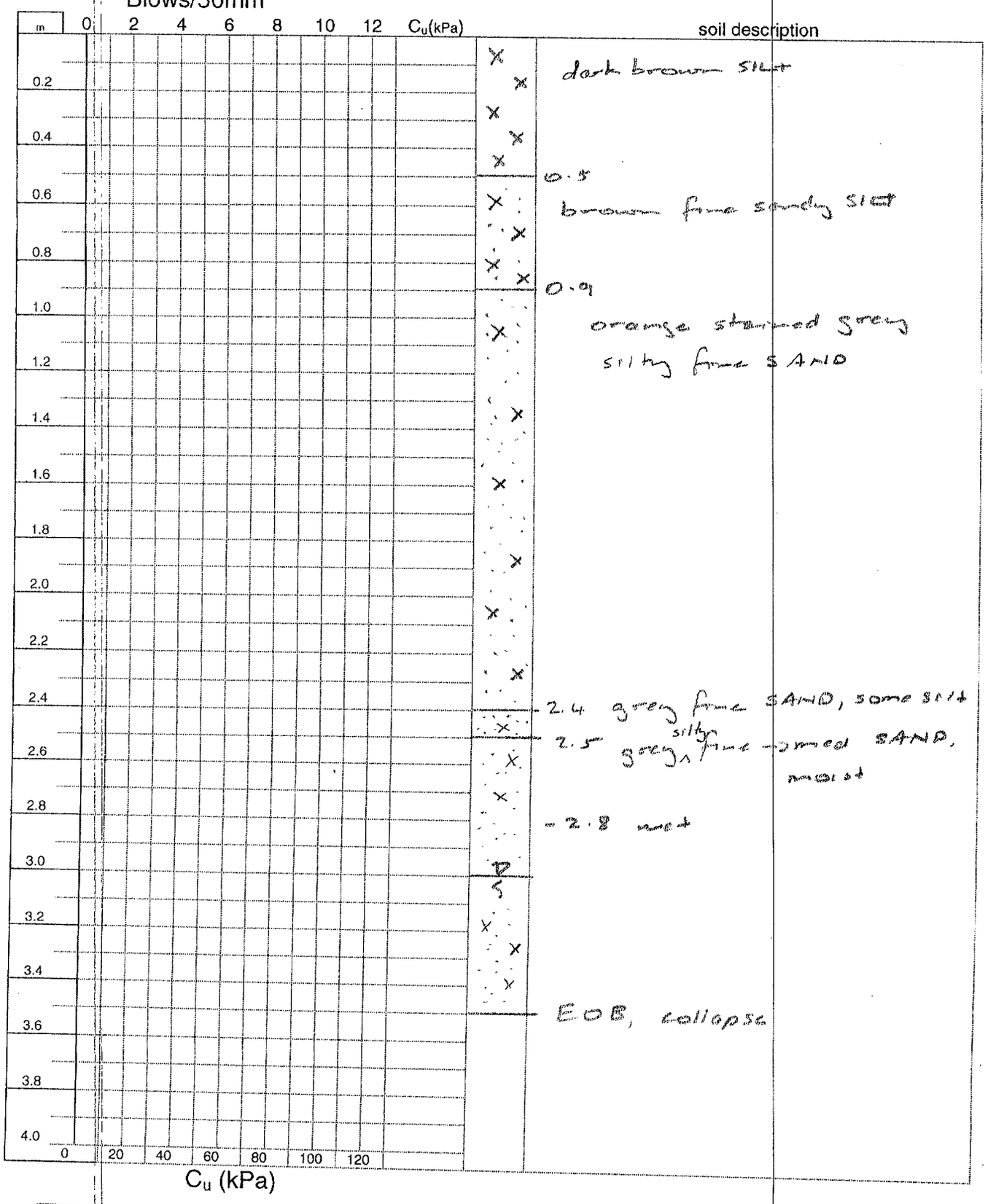
Hand Auger Log

Test Number: HA2

Job Name: Rangitaiki Stopbanks Section 13

Date: 26/6/06

Tested by: M.O'H



ICE GEO & CIVIL
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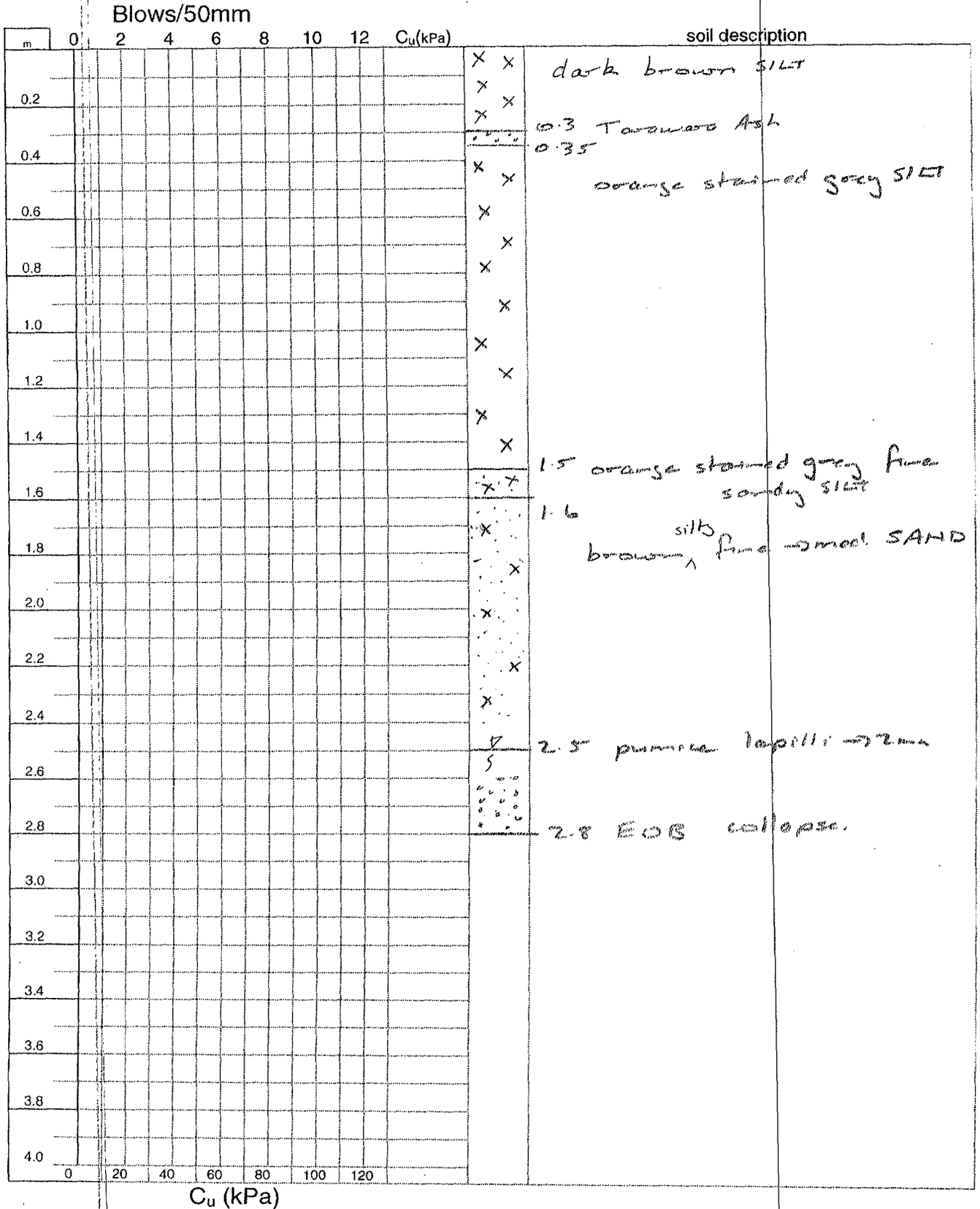
Hand Auger Log

Test Number: HA3

Job Name: Rangitaiki Shopbombs
Section 13

Date: 26/6/06

Tested by: M.O'H



ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

Hand Auger Log

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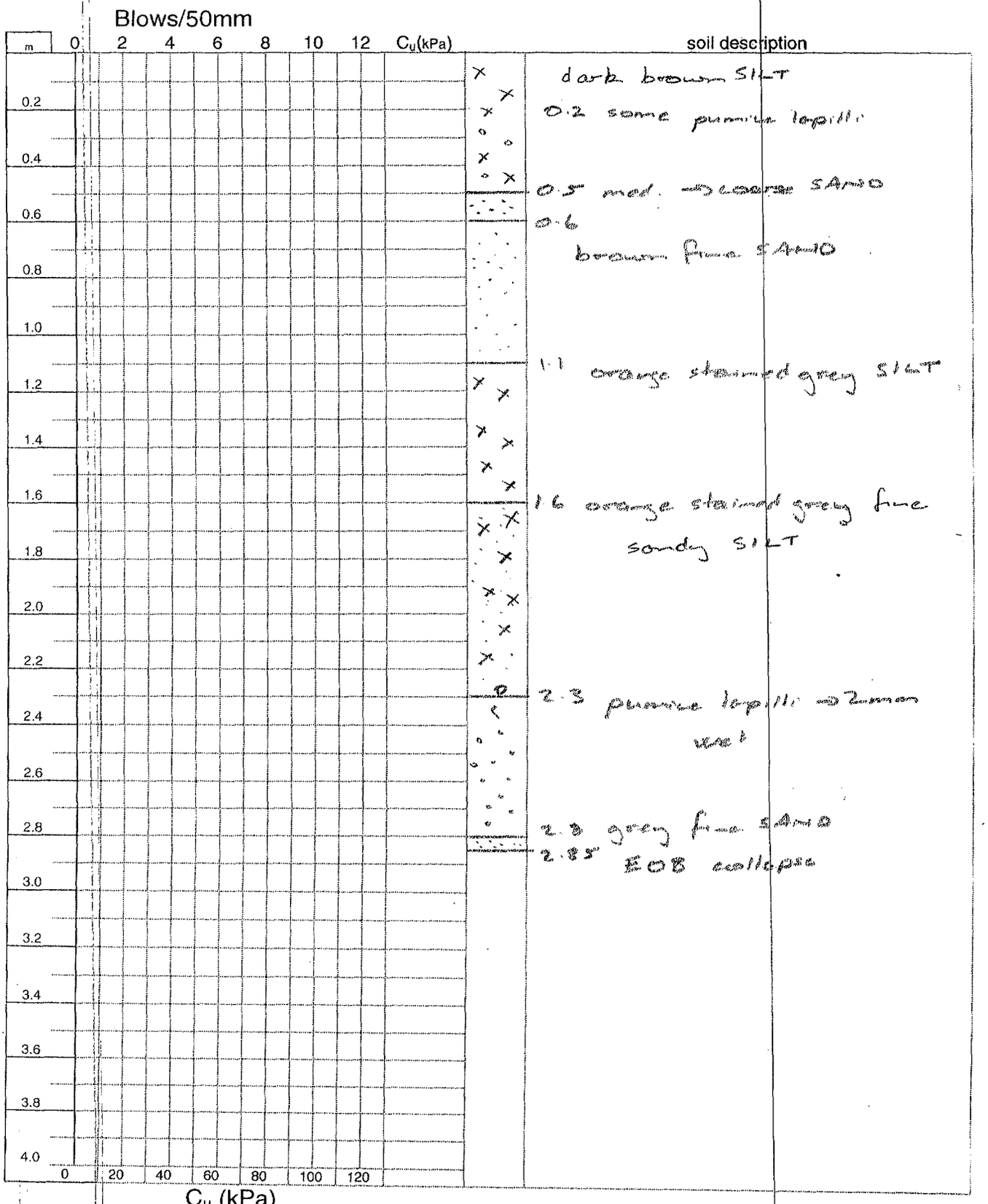
Job Name: Ramsitaiki Stopbanks Section 13

Date: 26/6/06

Tested by: M.O'H



ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

Hand Auger Log

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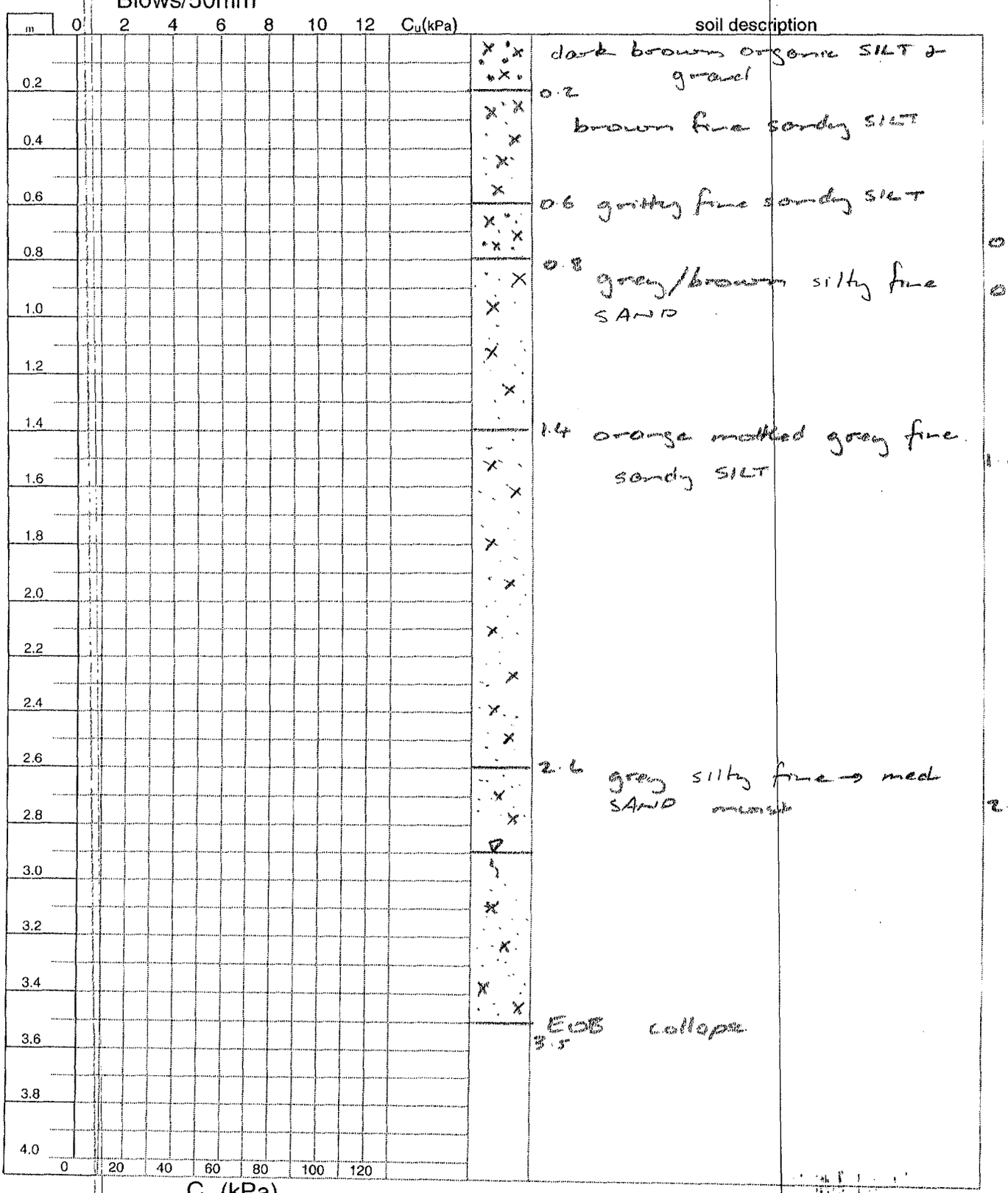
Job Name: Rangitaiki Stopbanks Section 13

Date: 21/6/6

Tested by: M.O'M



ICE GEO & CIVIL
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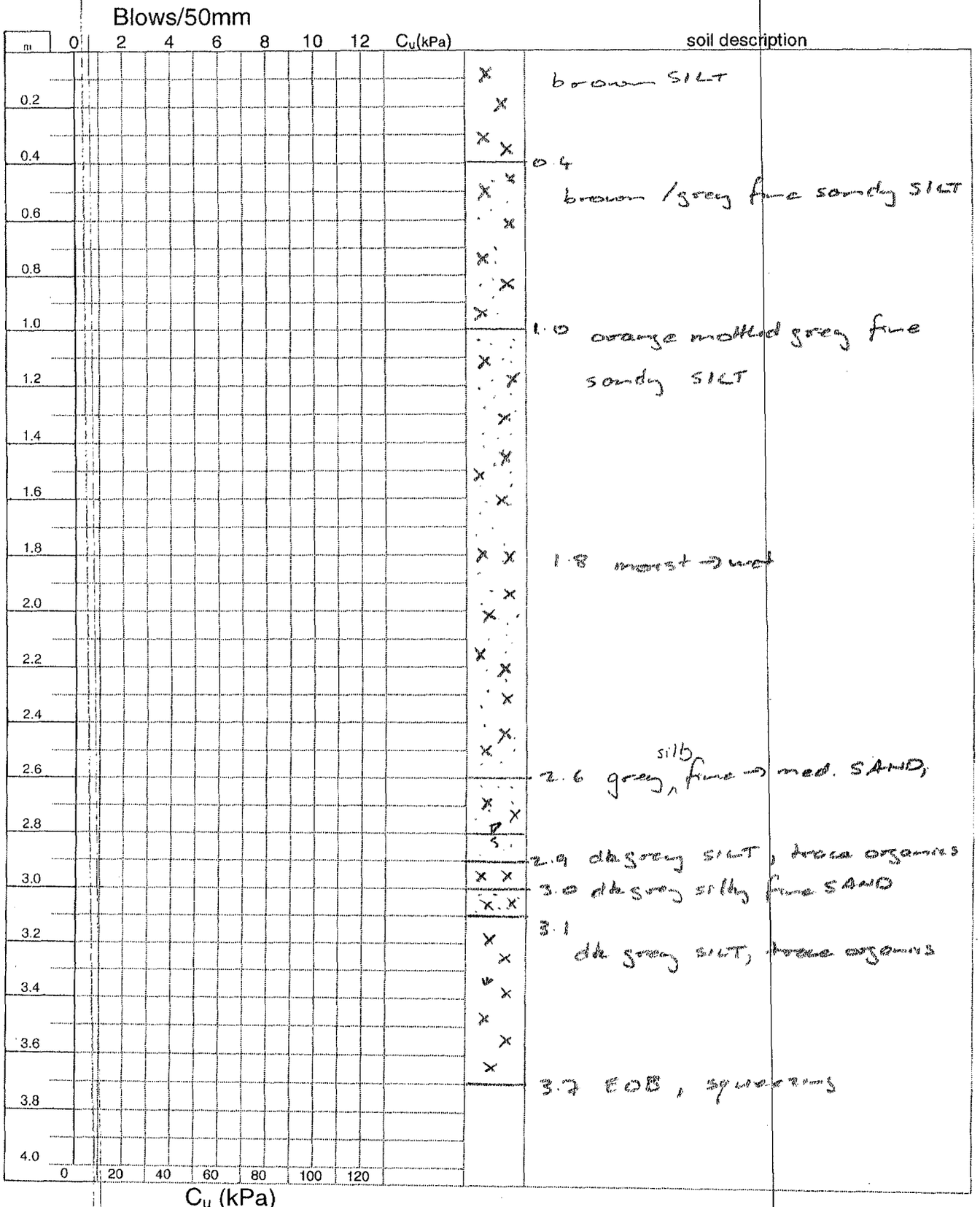
Hand Auger Log

Test Number: HA 6

Job Name: Rangitaiki Stopbanks Section 13

Date: 2.6/6/6

Tested by: M.O'H



ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

Hand Auger Log

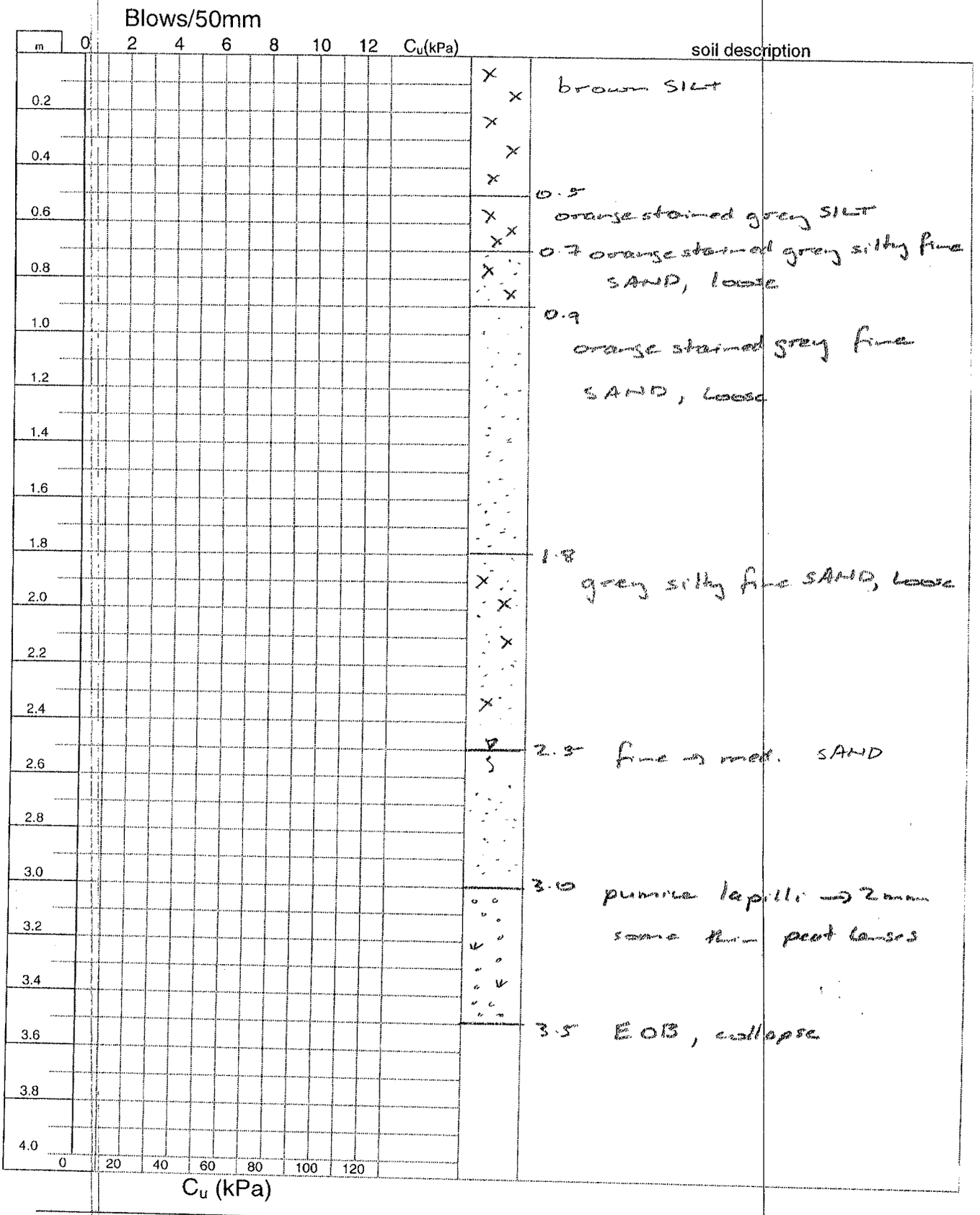
Test Number: HA7

Job Name: Rangiora Stopbanks Section 13

Date: 26/6/06

Tested by: M.O'M

level with culvert outlet



ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

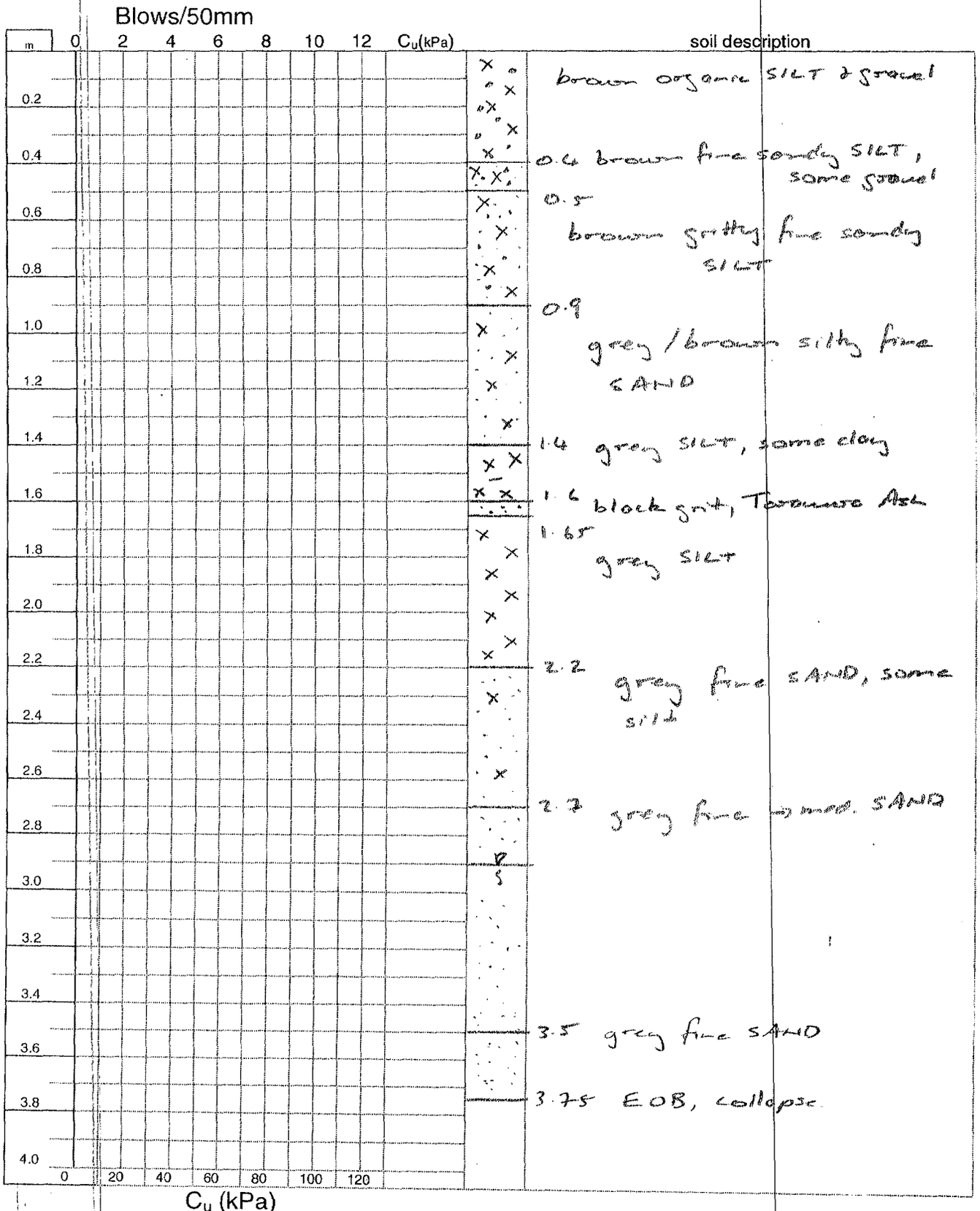
Hand Auger Log

Test Number: HA8

Job Name: Rangitaiki Stopbanks Section 13

Date: 21/6/06

Tested by: M.O'H



ICE GEO & CIVIL
A division of ICE CONSTRUCTION BV

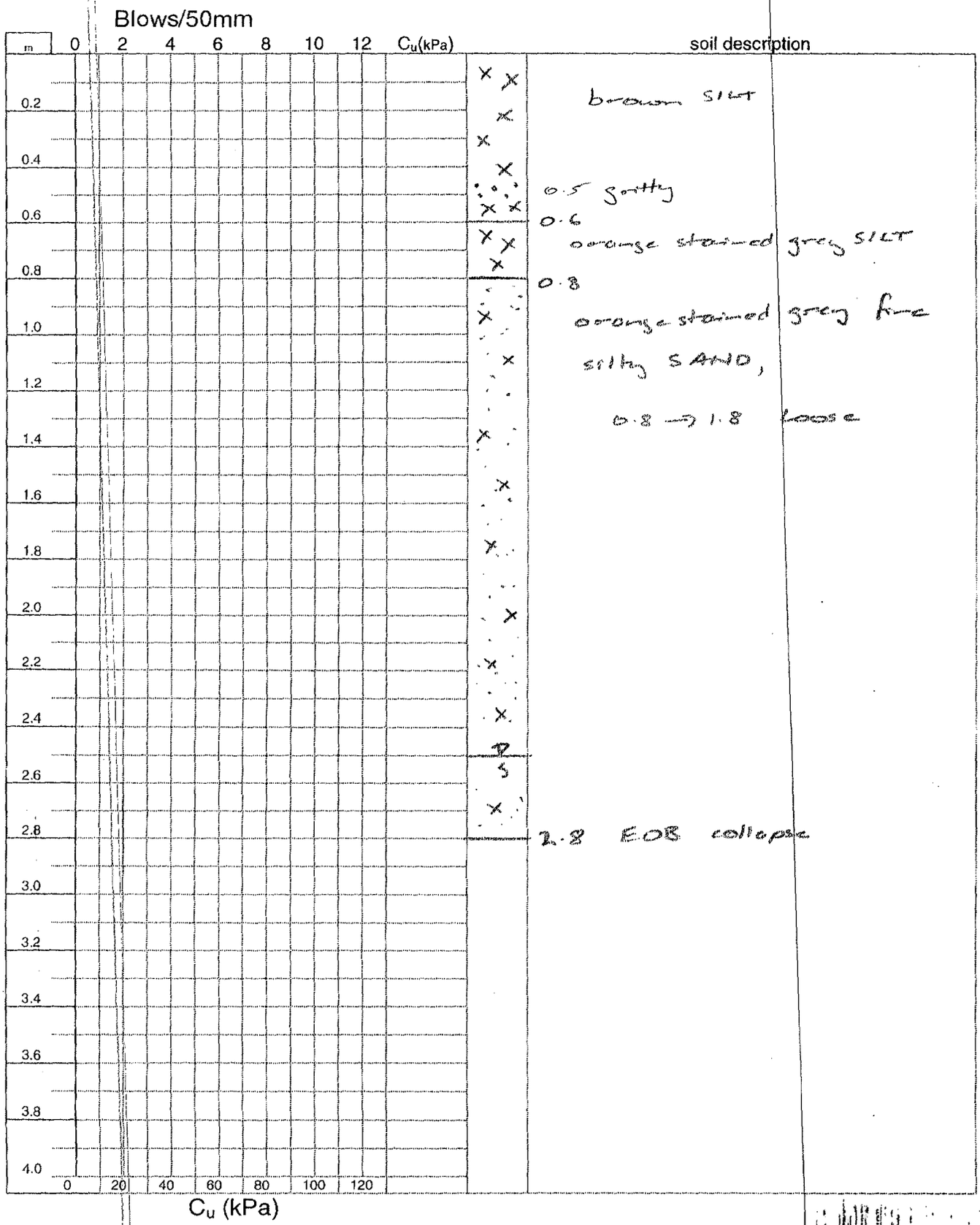
Hand Auger Log

Test Number: HA9

Job Name: Rangitaiki Stopbanks Section 13

Date: 26/6/06

Tested by: M.O'H



ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

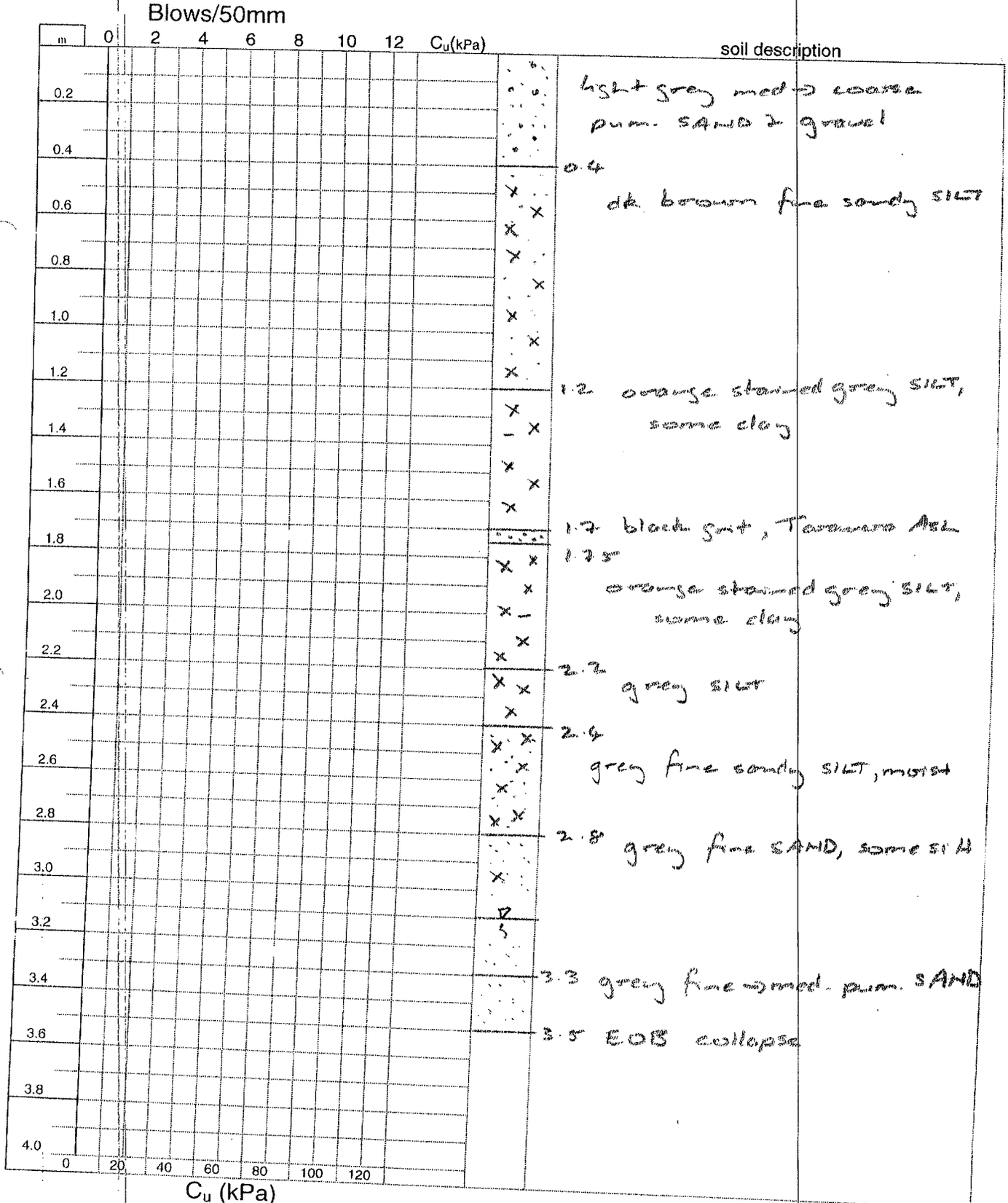
Hand Auger Log

Test Number: HA10

Job Name: Rangitaiki Stopbanks Section 13

Date: 21/6/06

Tested by: N.O.H



ICE GEO & CIVIL
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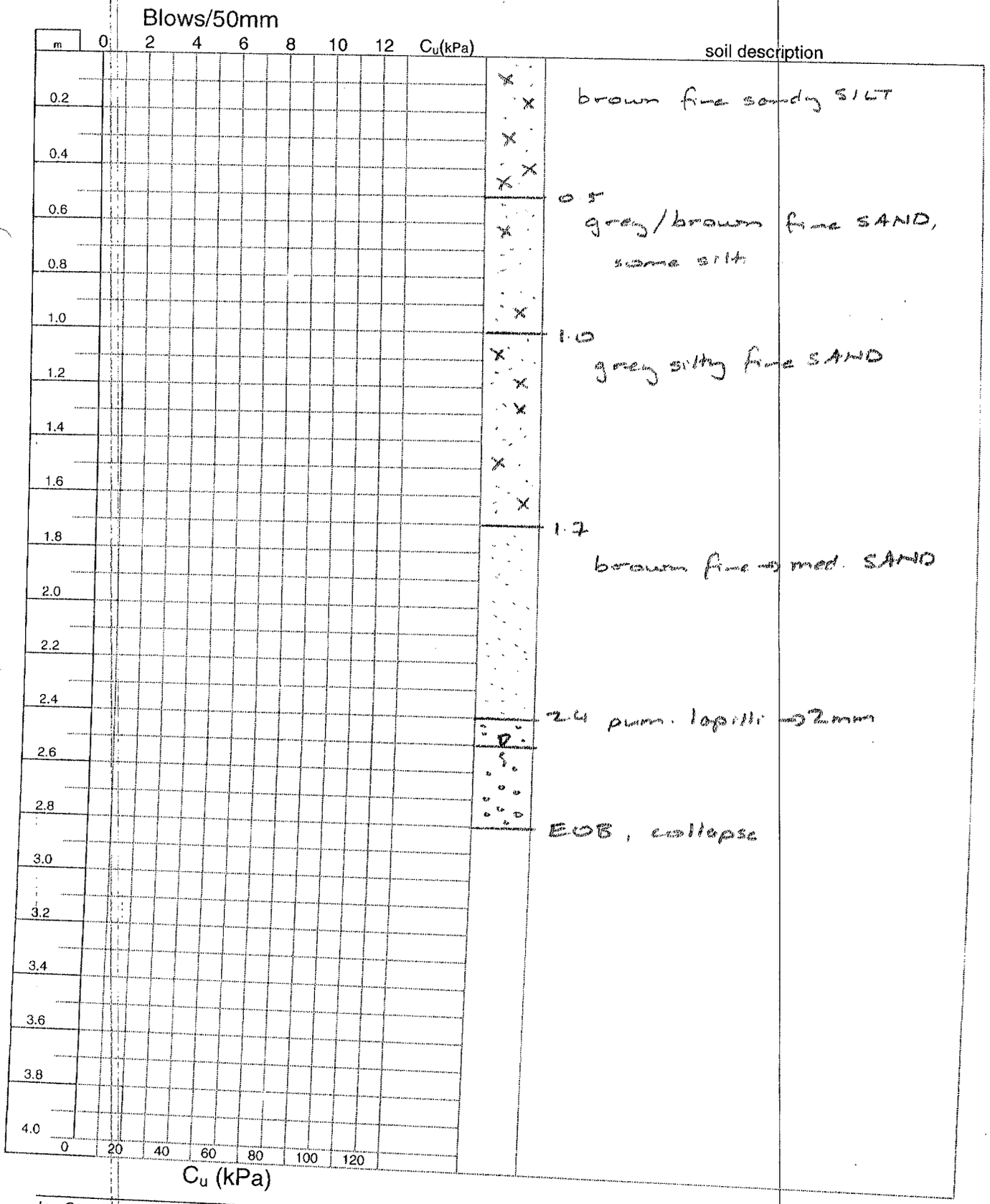
Hand Auger Log

Test Number: HA11

Job Name: Rangitaiki Shipboards Section 13

Date: 4/7/06

Tested by: M.O.H



ICE GEO & CIVIL
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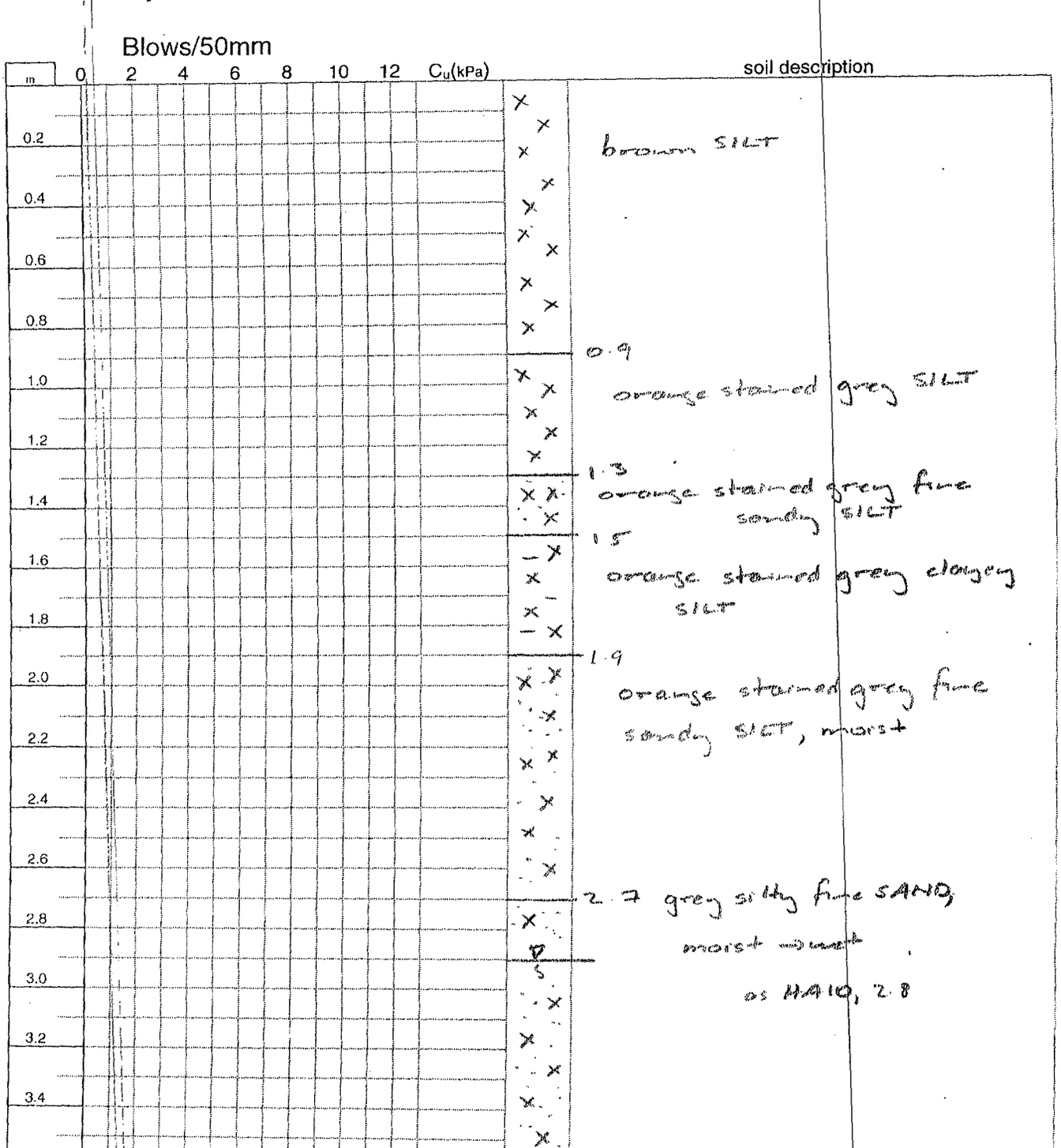
Hand Auger Log

Test Number: HA 12

Job Name: Rangitaiki Stopbanks Section 13

Date: 21/6/06

Tested by: M.O.H



ICE GEO & CIVIL
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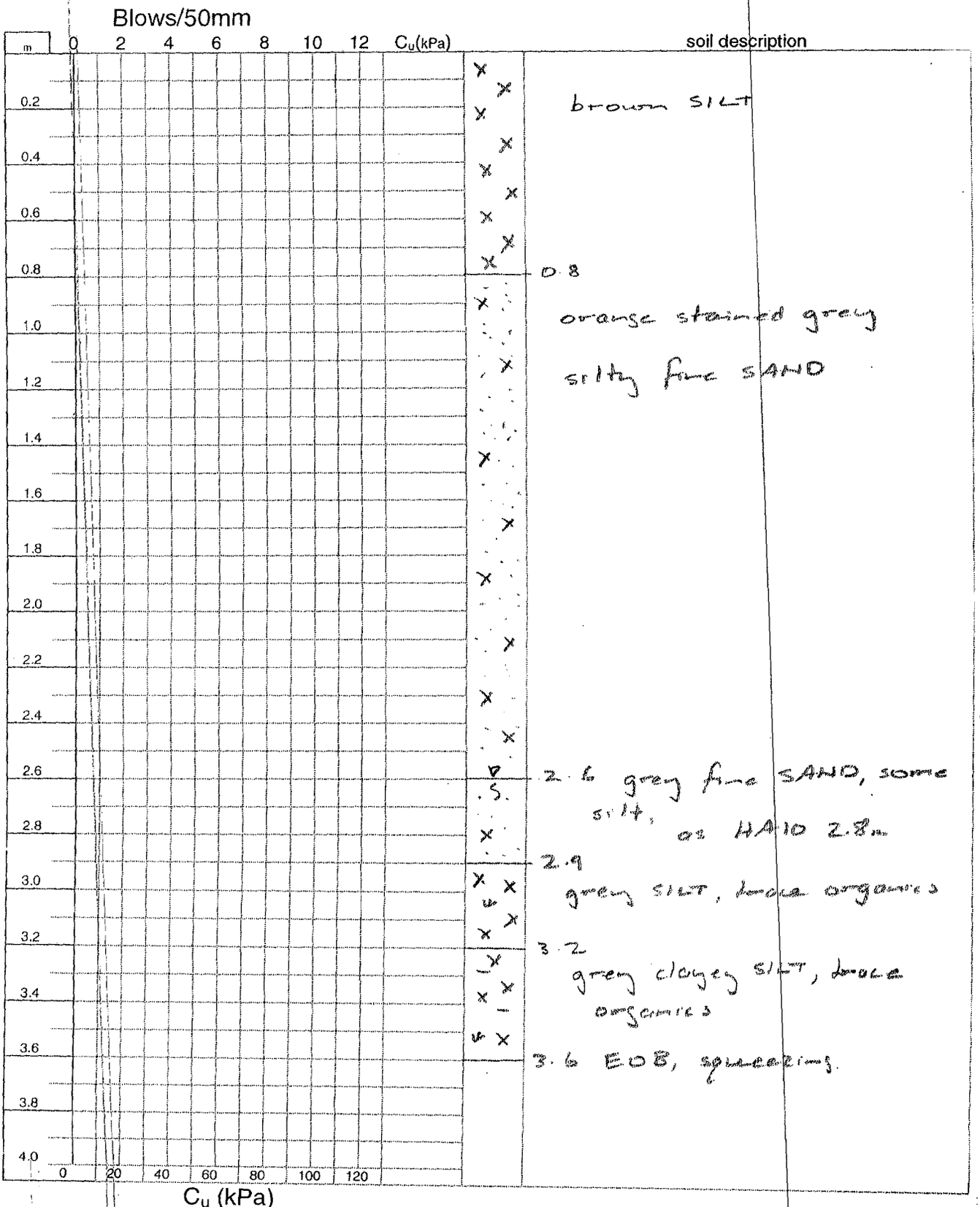
Hand Auger Log

Test Number: HA 12A

Job Name: Rangitaiki Stopbanks Section 13

Date: 21/6/06

Tested by: M.O'H



ICE GEO & CIVIL
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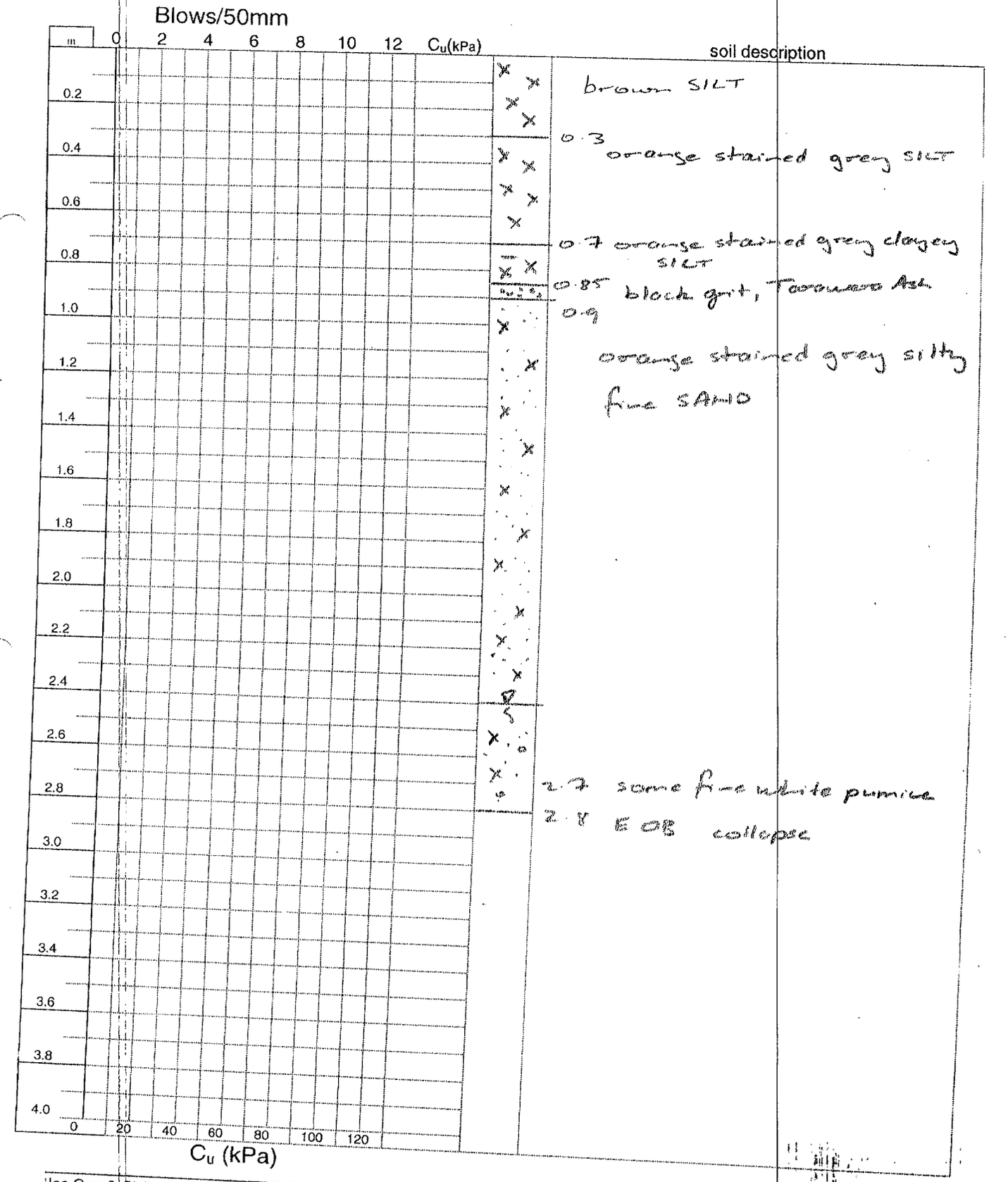
Hand Auger Log

Test Number: HA 13

Job Name: Rangitaiki Stopbanks Section 13

Date: 4/7/16

Tested by: M.O'H



ICE GEO & CIVIL
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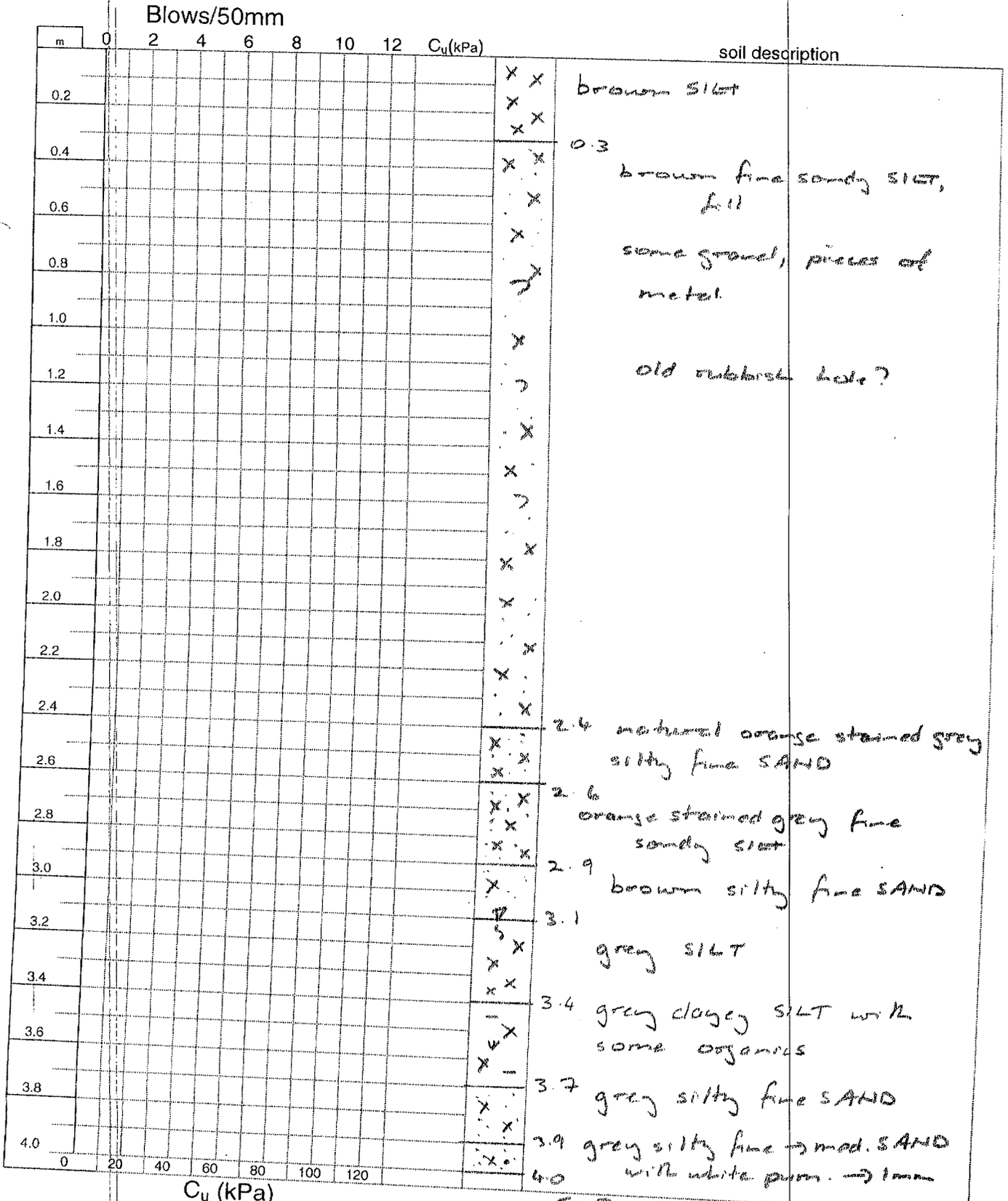
Hand Auger Log

Test Number: HA 14

Job Name: Rangitaiki Stopbanks Section 13

Date: 4/7/16

Tested by: M.O.M



ICE GEO & CIVIL
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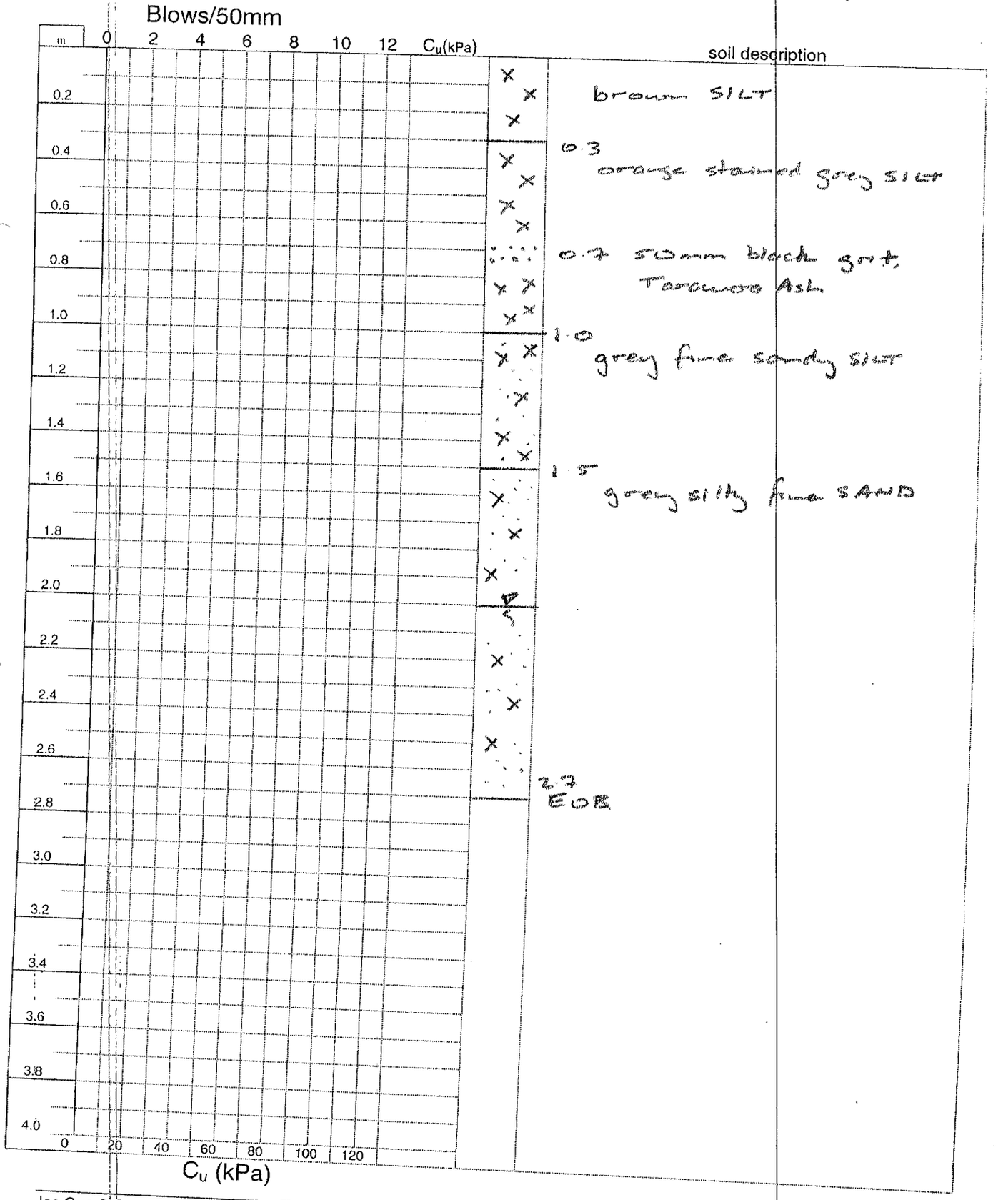
Hand Auger Log

Test Number: HA 15

Job Name: Rangitaiki Stopbanks Section 13

Date: 4/7/06

Tested by: M.O'H



ICE GEO & CIVIL
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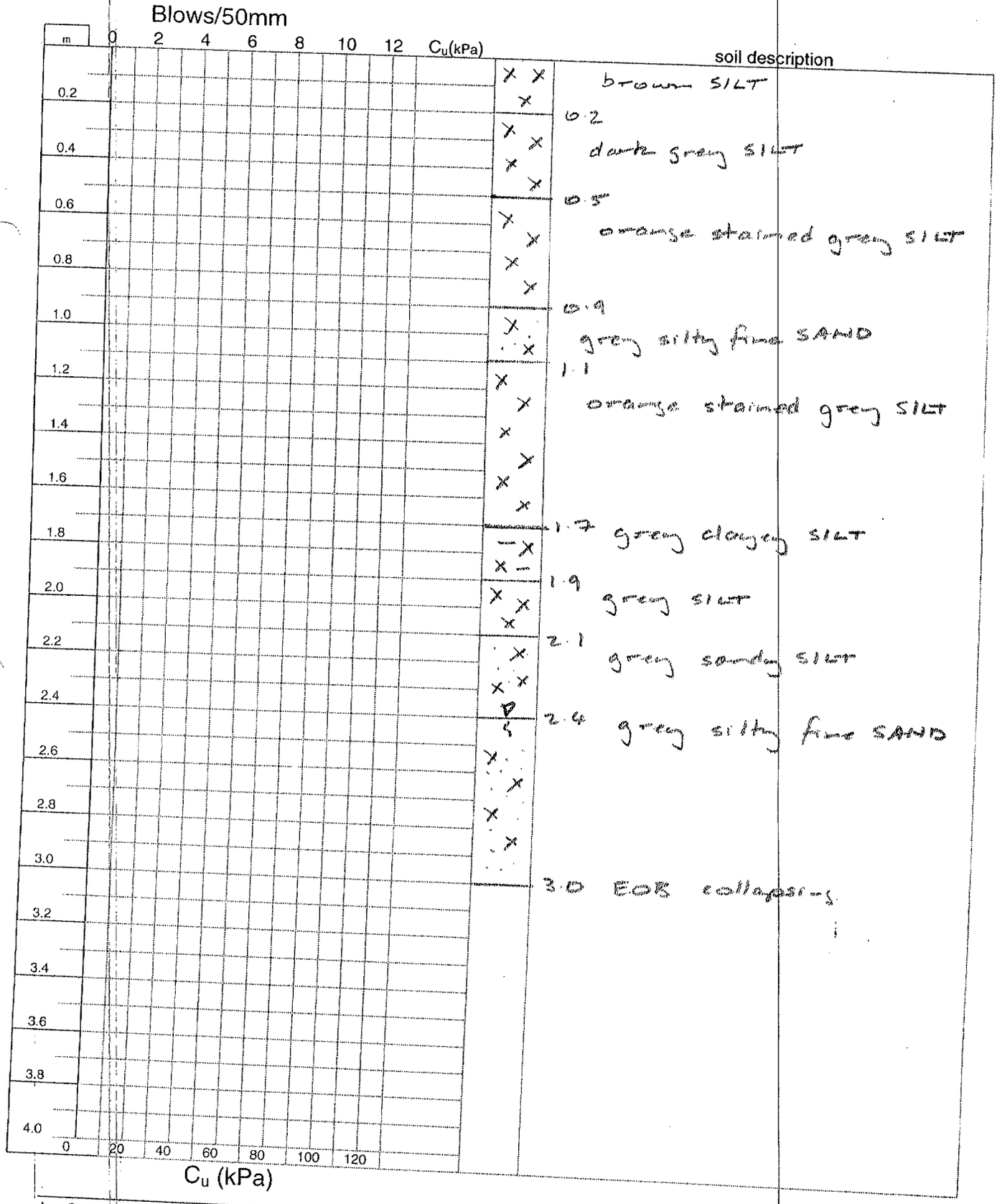
Hand Auger Log

Test Number: HA 16

Job Name: Rangitaiki Stopbanks Section 13

Date: 4/7/06

Tested by: M.O.H



ICE GEO & CIVIL
A division of ICE CONSTRUCTION LTD

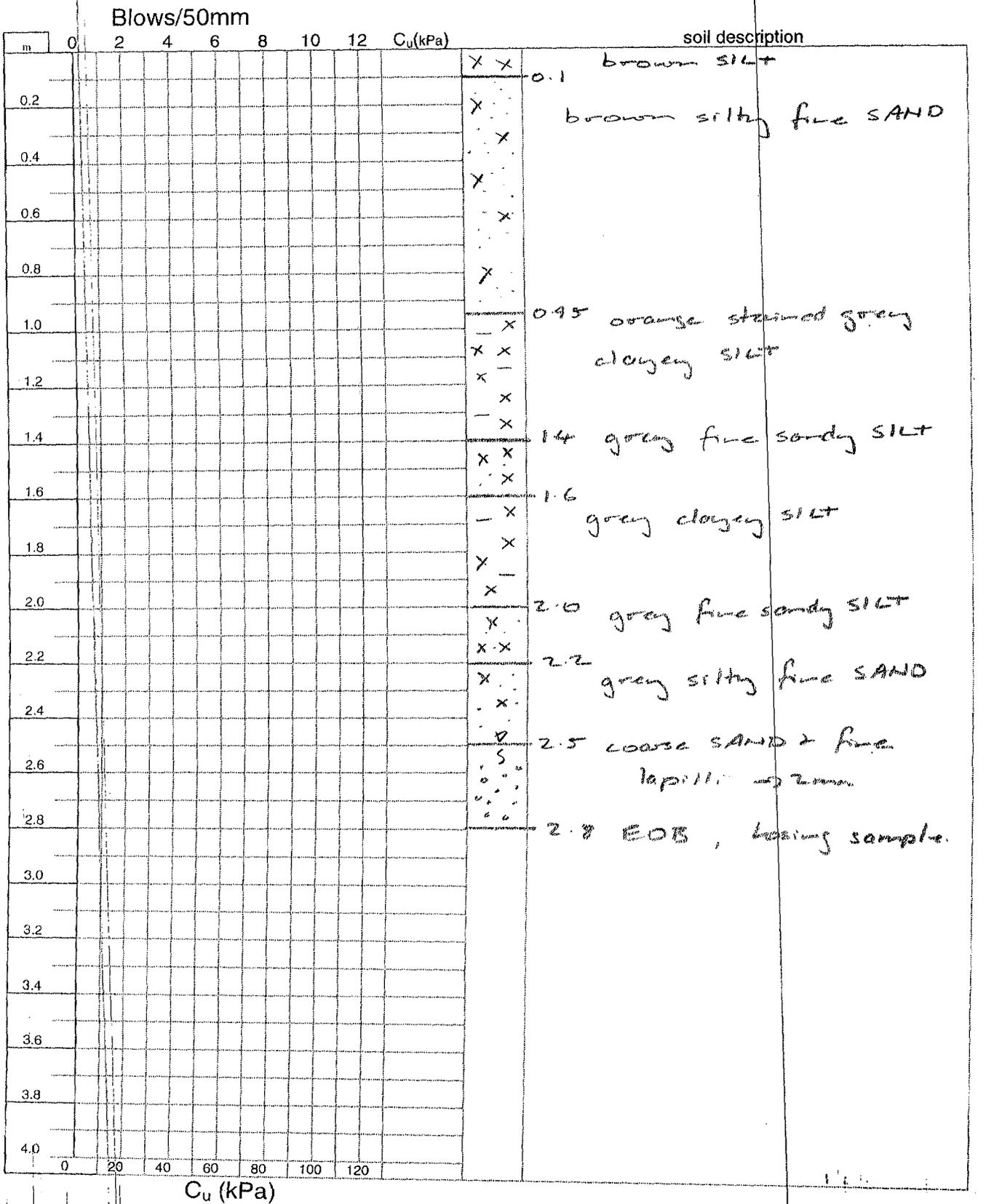
Hand Auger Log

Test Number: HA17

Job Name: Rangitaiki Stopbanks Section 13

Date: 3/7/06

Tested by: M.O'H



ICE GEO & CIVIL
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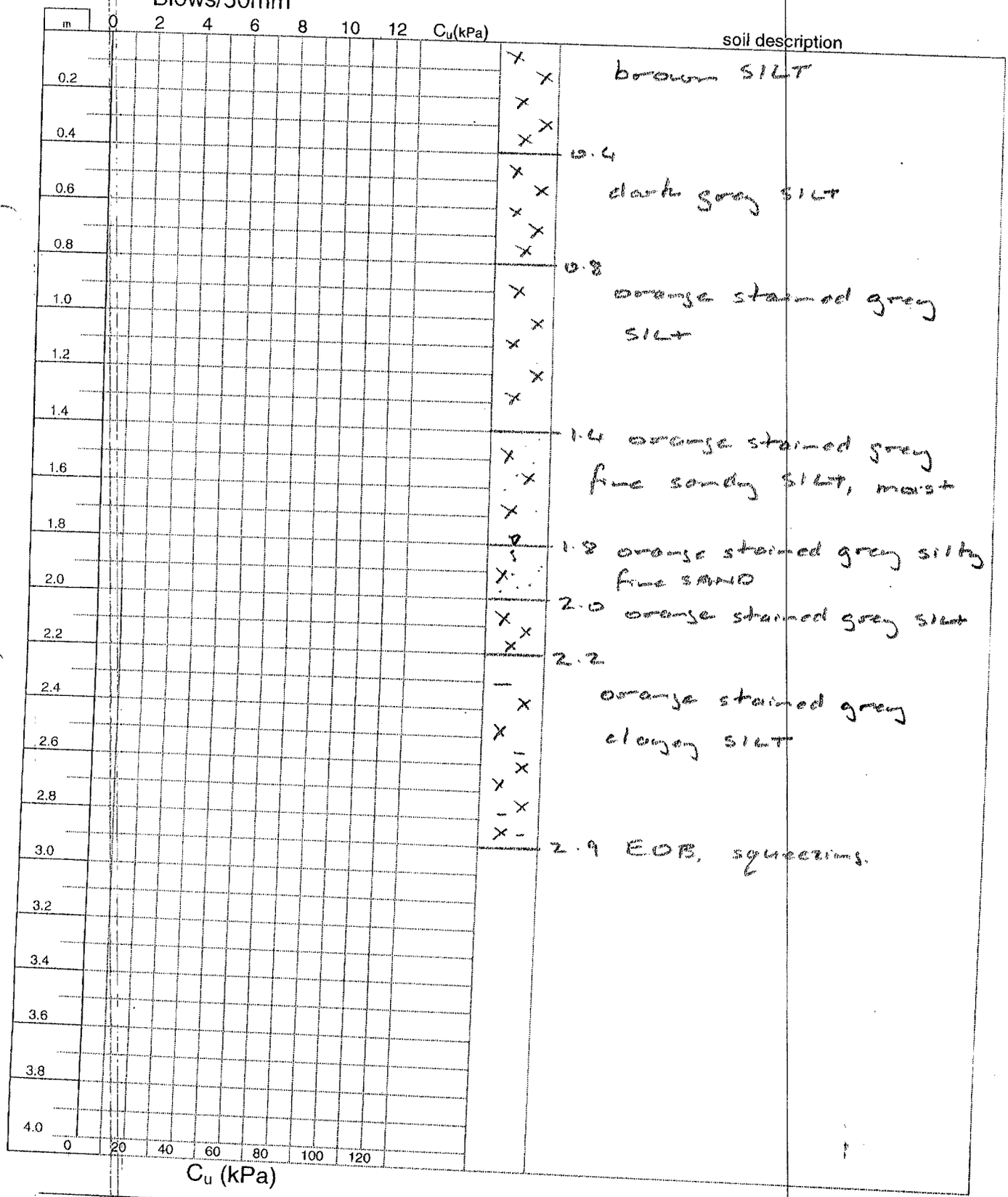
Hand Auger Log

Test Number: HA18

Job Name: Rangitaiki Stopbanks Section 13

Date: 4/7/06

Tested by: M.O'H



Appendix B

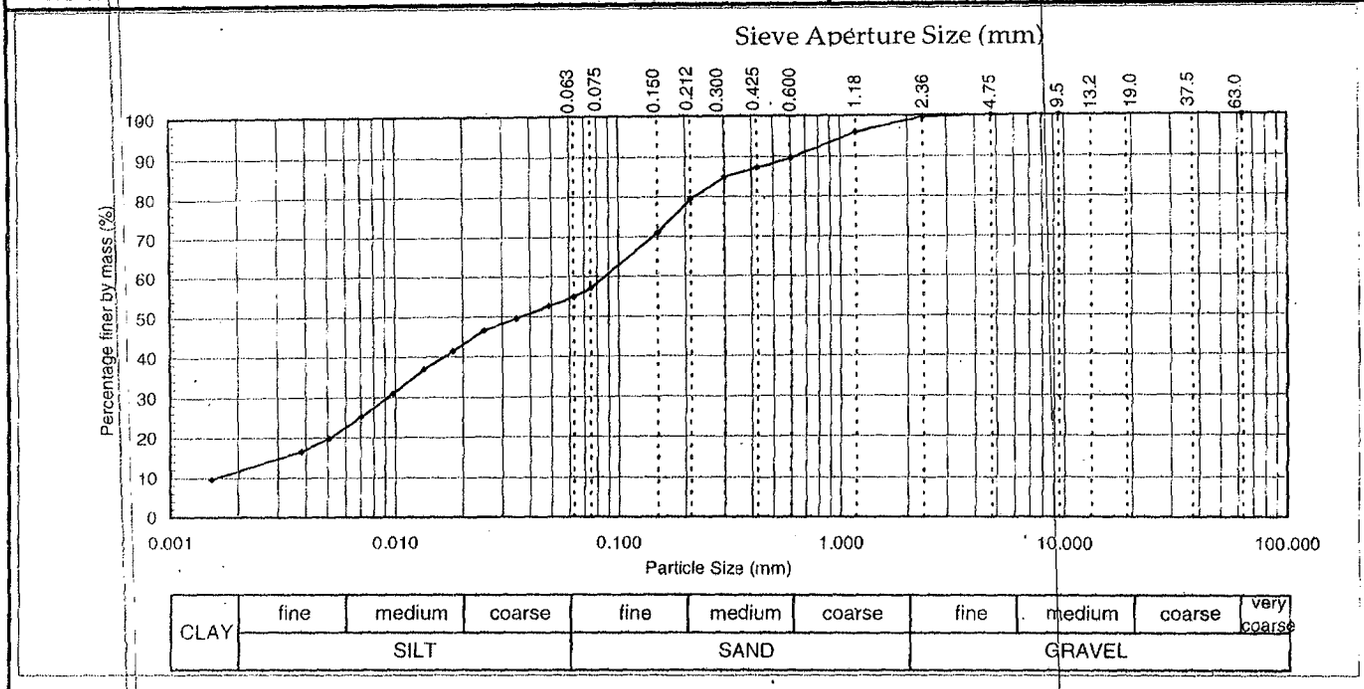
Laboratory Tests

PARTICLE SIZE ANALYSIS (HYDROMETER METHOD) TEST REPORT

Project : **Rangitaiki Stopbanks**
Location : **Rangitaiki**
Client : **Ice Geo & Civil Ltd, Papamoa**
Client/Sample Ref : -
Contractor : -
Sample ID: **HA5** Depth: **0.70 metres**
Sampled by : **Unknown**
Date received : **29/06/06**
Sampling method : **Auger**
Sample condition : **As received**
Sample description : **Brown Sandy SILT**
Solid Particle Density (t/m^3): **2.65** **Assumed**
Water Content (as received): **33.8** **%**

Project No: 2-68229.82
Lab Ref No: 06/229/006
Client Ref:

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	100	0.300	85	0.0485	52	0.0071	25
37.5	--	2.36	99	0.212	79	0.0348	49	0.0051	20
19.0	--	1.18	96	0.150	71	0.0249	46	0.0038	16
13.2	--	0.600	90	0.075	57	0.0180	41	0.0015	10
9.5	100	0.425	87	0.063	55	0.0135	37	--	--
Note:	"--" denotes sieve not used and/or hydrometer analysis not tested					0.0098	31		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.4 (Hydrometer Method)	pH of suspension : 8.0 Whatmans Full Range pH indicator paper

Date Tested: 3/07/06

Date Reported: 4/07/06

Sampling is not covered by IANZ Accreditation
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IANZ Approved Signatory
Designation : *Senior Civil Engineering Technician*
Date : 4/07/06

All tests reported herein have been performed in accordance with the laboratory's scope of accreditation

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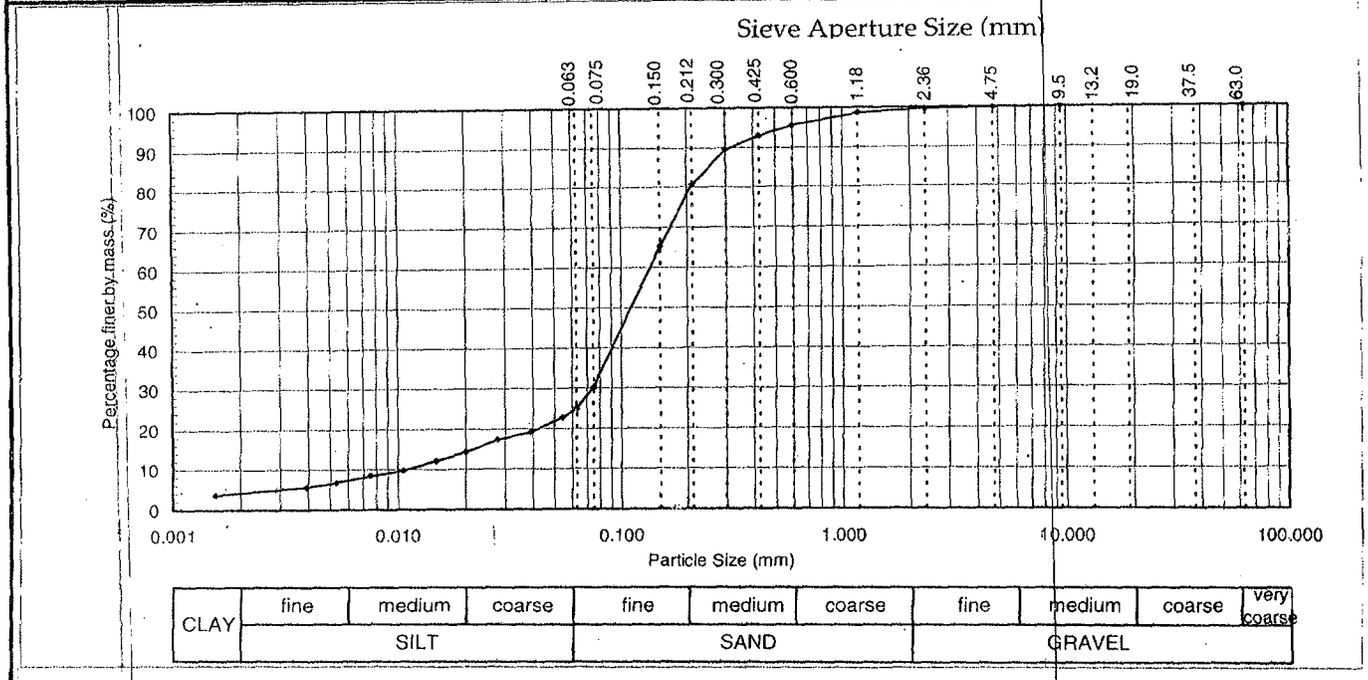
Website www.opus.co.nz

PARTICLE SIZE ANALYSIS (HYDROMETER METHOD) TEST REPORT

Project : **Rangitaiki Stopbanks**
Location : **Rangitaiki**
Client : **Ice Geo & Civil Ltd, Papamoa**
Client/Sample Ref : **-**
Contractor : **-**
Sample ID: **HA5** Depth: **0.90 metres**
Sampled by : **Unknown**
Date received : **29/06/06**
Sampling method : **Auger**
Sample condition : **As received**
Sample description : **Grey Silty fine SAND**
Solid Particle Density (t/m^3): **2.65** **Assumed**
Water Content (as received): **28.7** **%**

Project No: 2-68229.82
Lab Ref No: 06/229/006
Client Ref:

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	100	0.300	89	0.0542	23	0.0075	8
37.5	--	2.36	100	0.212	81	0.0392	19	0.0053	7
19.0	--	1.18	99	0.150	65	0.0278	17	0.0039	6
13.2	--	0.600	96	0.075	30	0.0200	14	0.0015	4
9.5	100	0.425	93	0.063	25	0.0147	12	--	--
Note:	"--" denotes sieve not used and/or hydrometer analysis not tested					0.0105	10		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.4 (Hydrometer Method)	pH of suspension : 8.0 Whatmans Full Range pH indicator paper

Date Tested: 3/07/06

Date Reported: 4/07/06

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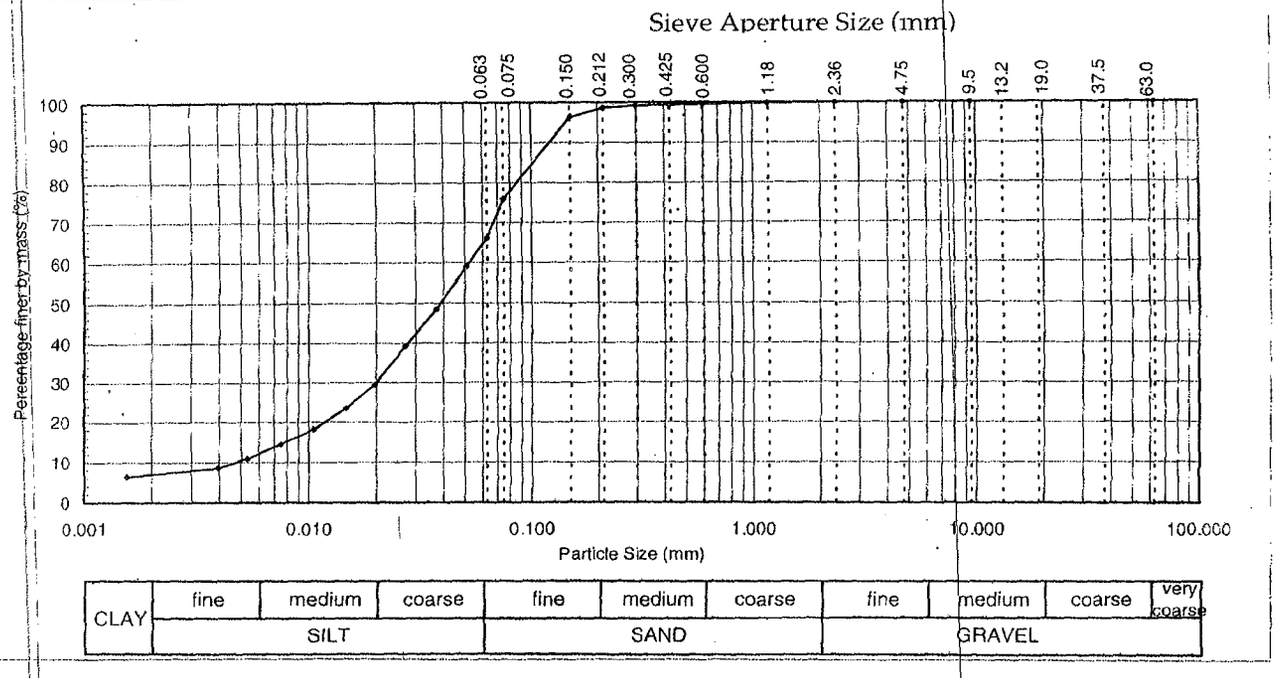
PARTICLE SIZE ANALYSIS (HYDROMETER METHOD) TEST REPORT

Project : **Rangitaiki Stopbanks**
Location : **Rangitaiki**
Client : **Ice Geo & Civil Ltd, Papamoa**
Client/Sample Ref : **-**
Contractor : **-**
Sample ID: **HA5** Depth: **1.50 metres**
Sampled by : **Unknown**
Date received : **29/06/06**
Sampling method : **Auger**
Sample condition : **As received**
Sample description : **Grey Sandy SILT**
Solid Particle Density (t/m^3): **2.65** **Assumed**
Water Content (as received): **44.1** **%**

Project No: 2-68229.82
Lab Ref No: 06/229/006
Client Ref:

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	100	0.300	99	0.0507	59	0.0075	15
37.5	--	2.36	100	0.212	99	0.0373	48	0.0053	11
19.0	--	1.18	100	0.150	96	0.0270	39	0.0040	8
13.2	--	0.600	100	0.075	76	0.0197	29	0.0015	6
9.5	100	0.425	99	0.063	66	0.0146	23	--	--
Note:	"--" denotes sieve not used and/or hydrometer analysis not tested					0.0105	18		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.4 (Hydrometer Method)	pH of suspension : 8.0 Whatmans Full Range pH indicator paper

Date Tested: 3/07/06

Date Reported: 4/07/06

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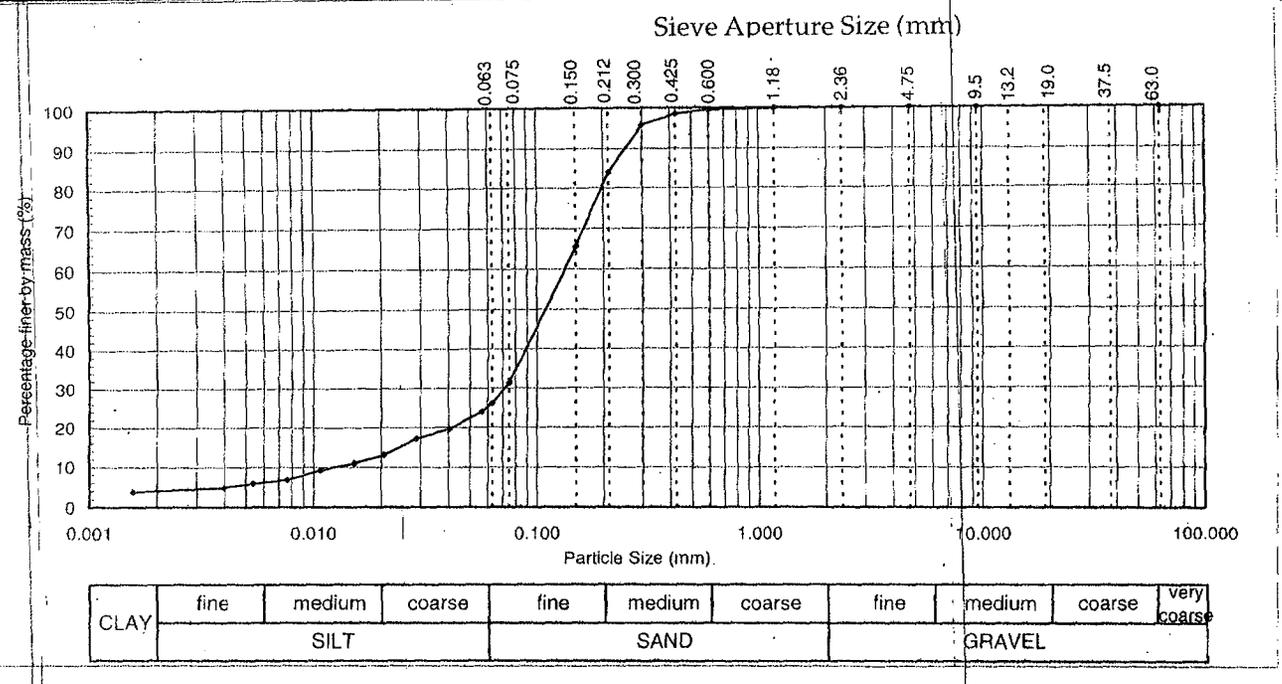
PARTICLE SIZE ANALYSIS (HYDROMETER METHOD) TEST REPORT

Project : **Rangitaiki Stopbanks**
Location : **Rangitaiki**
Client : **Ice Geo & Civil Ltd, Papamoa**
Client/Sample Ref : **-**
Contractor : **-**
Sample ID: **HA5** Depth: **2.70 metres**
Sampled by : **Unknown**
Date received : **29/06/06**
Sampling method : **Auger**
Sample condition : **As received**
Sample description : **Grey Silty SAND**
Solid Particle Density (t/m^3): **2.65** **Assumed**
Water Content (as received): **48.1** **%**

Project No: 2-68229.82
Lab Ref No: 06/229/006
Client Ref:

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	100	0.300	96	0.0563	24	0.0076	7
37.5	--	2.36	100	0.212	84	0.0404	20	0.0054	6
19.0	--	1.18	100	0.150	65	0.0286	17	0.0040	5
13.2	--	0.600	99	0.075	31	0.0205	13	0.0016	4
9.5	100	0.425	99	0.063	26	0.0151	11	--	--
Note:	"--" denotes sieve not used and/or hydrometer analysis not tested					0.0107	9		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.4 (Hydrometer Method)	pH of suspension : 8.0 Whatmans Full Range pH indicator paper

Date Tested: 3/07/06

Date Reported: 4/07/06

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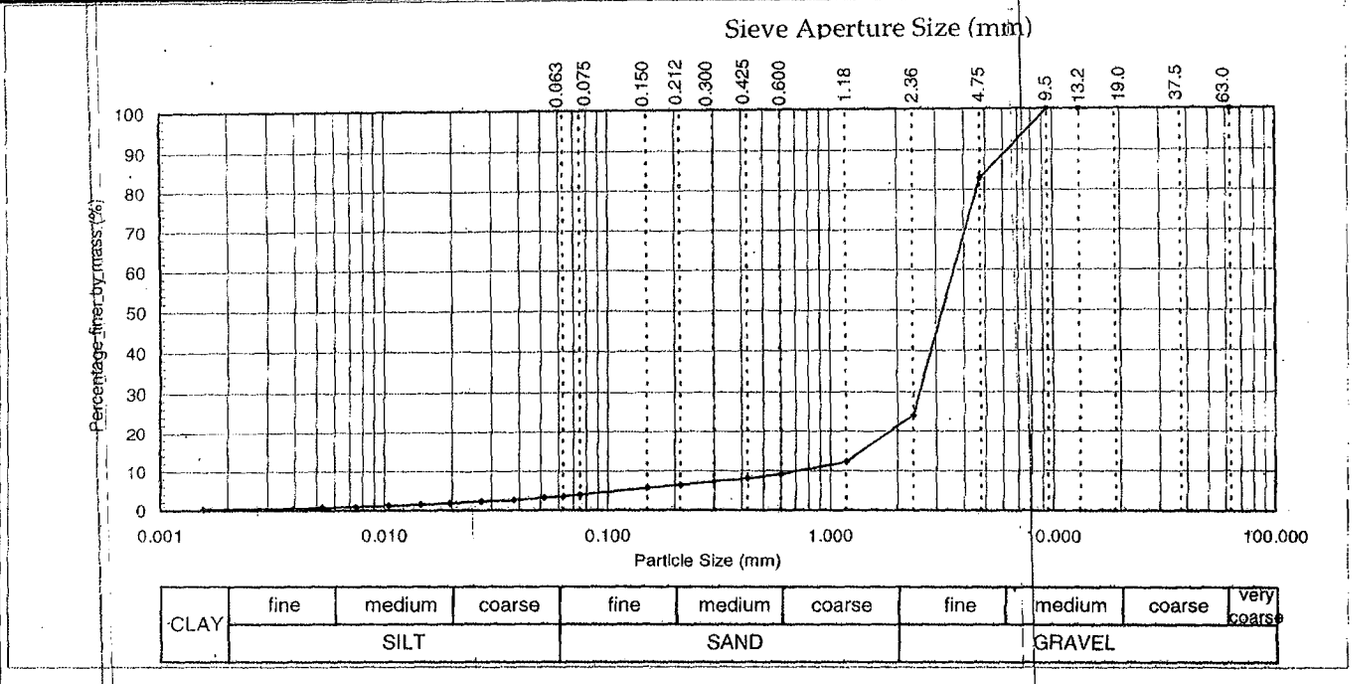
PARTICLE SIZE ANALYSIS (HYDROMETER METHOD)
TEST REPORT

Project : **Rangitaiki Stopbanks**
Location : **Rangitaiki**
Client : **Ice Geo & Civil Ltd, Papamoa**
Client/Sample Ref : **Drainage Sample**
Contractor : -
Sample ID: **#5** Depth:
Sampled by : **Unknown**
Date received : **29/06/06**
Sampling method : **Unknown**
Sample condition : **As received**
Sample description : **Greyish brown GRAVEL**
Solid Particle Density (t/m^3): **2.65** **Assumed**
Water Content (as received): **4.0** **%**

Project No: 2-68229.82
Lab Ref No: 06/229/006
Client Ref:

Sieve Analysis						Hydrometer Analysis			
Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Sieve Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)	Particle Size (mm)	Passing (%)
63.0	--	4.75	83	0.300	7	0.0517	3	0.0075	1
37.5	--	2.36	24	0.212	6	0.0379	3	0.0053	1
19.0	--	1.18	12	0.150	6	0.0270	2	0.0039	1
13.2	100	0.600	9	0.075	4	0.0196	2	0.0016	0
9.5	100	0.425	8	0.063	4	0.0145	2	--	--
Note: "--" denotes sieve not used and/or hydrometer analysis not tested						0.0104	1		



Test Methods	Notes
Particle Size Analysis: NZS 4402:1986: Test 2.8.4 (Hydrometer Method)	pH of suspension : 8.0 Whatmans Full Range pH indicator paper

Date Tested: 3/07/06

Date Reported: 4/07/06

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Appendix C

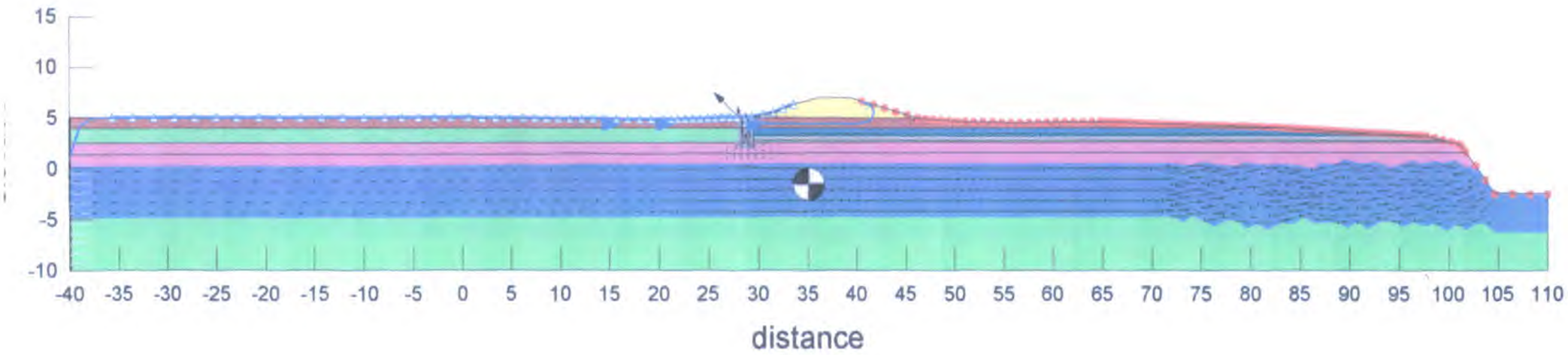
Seepage Models

Name: cross section 1 100 yr.gsz
Comments: cross section 1 100 yr flood
Date: 05/08/2006 Time: 11:15:19 p.m.

time step 40 - 80 hours

2.5m deep toe drain

Material #: 1	Description:	Hyd K Fn: 1	Vol WC Fn: 1	Ky/Kx Ratio: 0.5	Direction of Kx: 0
Material #: 2	Description:	Hyd K Fn: 2	Vol WC Fn: 2	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 3	Description:	Hyd K Fn: 3	Vol WC Fn: 3	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 4	Description:	Hyd K Fn: 4	Vol WC Fn: 4	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 5	Description:	Hyd K Fn: 5	Vol WC Fn: 5	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 6	Description:	Hyd K Fn: 6	Vol WC Fn: 6	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 7	Description:	Hyd K Fn: 7	Vol WC Fn: 7	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 8	Description:	Hyd K Fn: 8	Vol WC Fn: 8	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 9	Description:	Hyd K Fn: 9	Vol WC Fn: 9	Ky/Kx Ratio: 1	Direction of Kx: 0

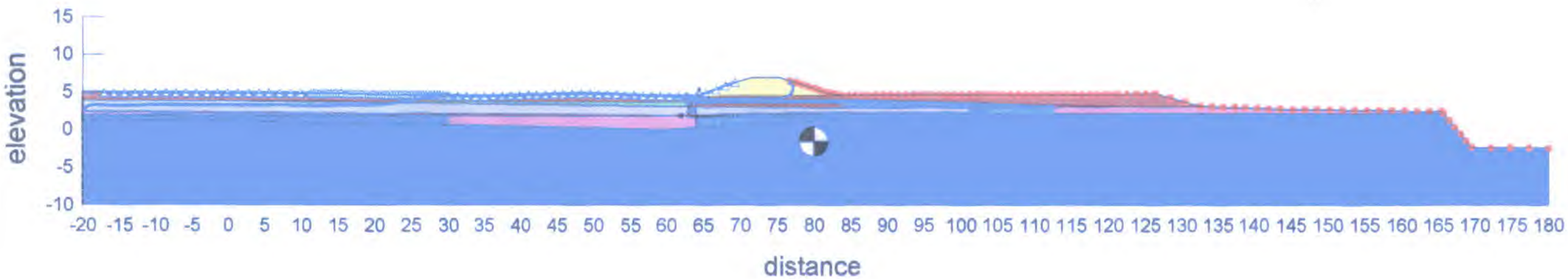


Name: cross section 2 100 yr.gsz
Comments: cross section 2 100 yr flood
Date: 05/08/2006 Time: 9:05:46 p.m.

Times step 40 - 80 hours

toe drain 2.5m deep

Material #: 1	Description:	Hyd K Fn: 1	Vol WC Fn: 1	Ky/Kx Ratio: 0.5	Direction of Kx: 0
Material #: 2	Description:	Hyd K Fn: 2	Vol WC Fn: 2	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 3	Description:	Hyd K Fn: 3	Vol WC Fn: 3	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 4	Description:	Hyd K Fn: 4	Vol WC Fn: 4	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 5	Description:	Hyd K Fn: 5	Vol WC Fn: 5	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 6	Description:	Hyd K Fn: 6	Vol WC Fn: 6	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 7	Description:	Hyd K Fn: 7	Vol WC Fn: 7	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 8	Description:	Hyd K Fn: 8	Vol WC Fn: 8	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 9	Description:	Hyd K Fn: 9	Vol WC Fn: 9	Ky/Kx Ratio: 1	Direction of Kx: 0

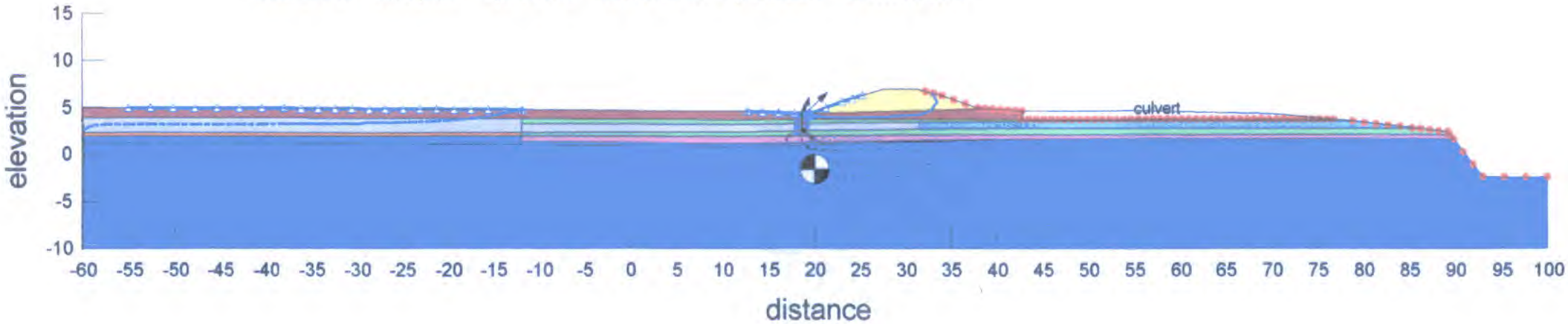


Name: cross section 3 100 yr.gsz
Title: Rangitaiki Stopbanks Section 13
Comments: Cross section 3 static
Date: 09/08/2006 Time: 11:03:50 a.m.

time step 40 80 hours

2.5m deep toe drain
allowance for squash club building
allowance for culvert outlet

Material #: 1 Description: Hyd K Fn: 1 Vol WC Fn: 1 Ky/Kx Ratio: 0.5 Direction of Kx: 0
Material #: 2 Description: Hyd K Fn: 2 Vol WC Fn: 2 Ky/Kx Ratio: 1 Direction of Kx: 0
Material #: 3 Description: Hyd K Fn: 3 Vol WC Fn: 3 Ky/Kx Ratio: 1 Direction of Kx: 0
Material #: 4 Description: Hyd K Fn: 4 Vol WC Fn: 4 Ky/Kx Ratio: 1 Direction of Kx: 0
Material #: 5 Description: Hyd K Fn: 5 Vol WC Fn: 5 Ky/Kx Ratio: 1 Direction of Kx: 0
Material #: 6 Description: Hyd K Fn: 6 Vol WC Fn: 6 Ky/Kx Ratio: 1 Direction of Kx: 0
Material #: 7 Description: Hyd K Fn: 7 Vol WC Fn: 7 Ky/Kx Ratio: 1 Direction of Kx: 0
Material #: 8 Description: Hyd K Fn: 8 Vol WC Fn: 8 Ky/Kx Ratio: 1 Direction of Kx: 0
Material #: 9 Description: Hyd K Fn: 9 Vol WC Fn: 9 Ky/Kx Ratio: 0.5 Direction of Kx: 0
Material #: 10 Description: Hyd K Fn: 10 Vol WC Fn: 10 Ky/Kx Ratio: 1 Direction of Kx: 0

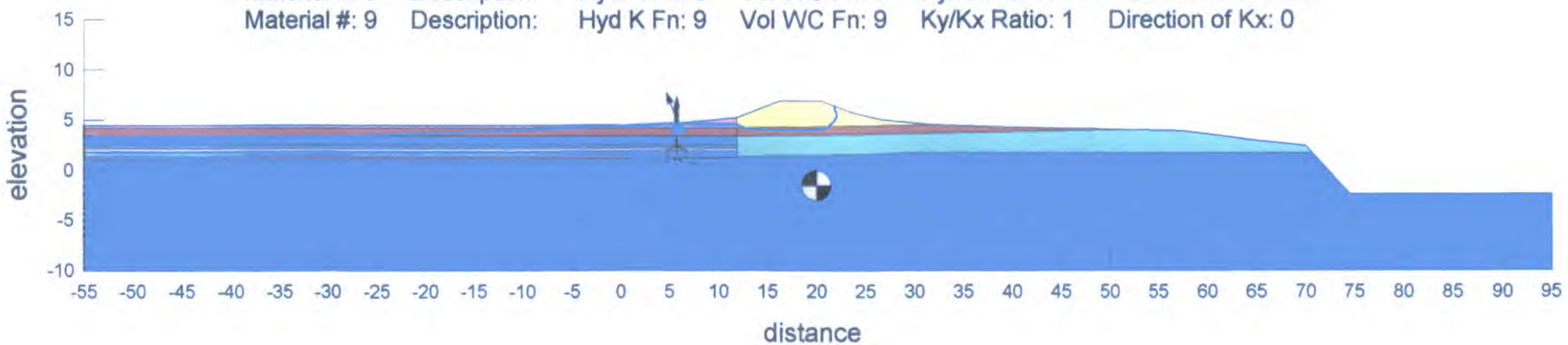


Name: cross section 4 100 yr.gsz
Title: Rangitaiki Stopbanks Section 13
Comments: cross section 4 100 yr flood
Date: 09/08/2006 Time: 2:01:11 p.m.

time step 40 80 hours

3m deep pressure relief trench

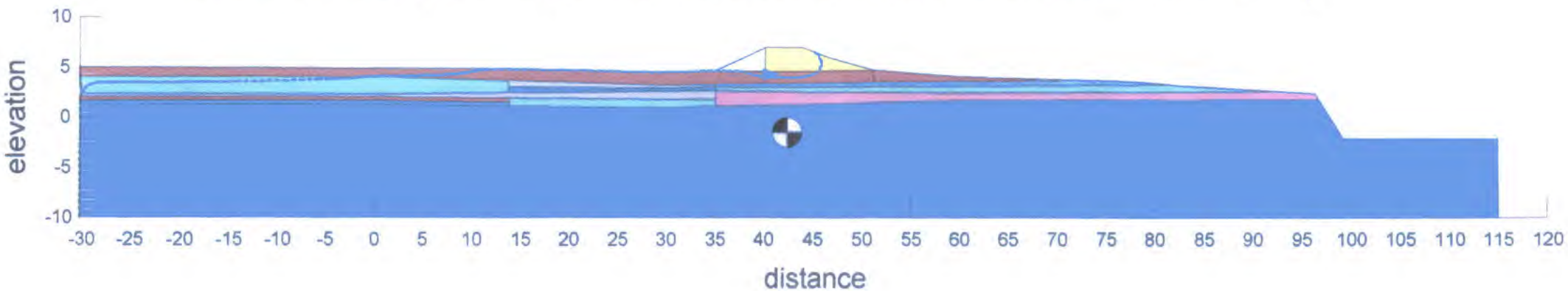
Material #: 1	Description:	Hyd K Fn: 1	Vol WC Fn: 1	Ky/Kx Ratio: 0.5	Direction of Kx: 0
Material #: 2	Description:	Hyd K Fn: 2	Vol WC Fn: 2	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 3	Description:	Hyd K Fn: 3	Vol WC Fn: 3	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 4	Description:	Hyd K Fn: 4	Vol WC Fn: 4	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 5	Description:	Hyd K Fn: 5	Vol WC Fn: 5	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 6	Description:	Hyd K Fn: 6	Vol WC Fn: 6	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 7	Description:	Hyd K Fn: 7	Vol WC Fn: 7	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 8	Description:	Hyd K Fn: 8	Vol WC Fn: 8	Ky/Kx Ratio: 0.5	Direction of Kx: 0
Material #: 9	Description:	Hyd K Fn: 9	Vol WC Fn: 9	Ky/Kx Ratio: 1	Direction of Kx: 0



Name: cross section 5 100 yr.gsz
Title: Rangitaiki Stopbanks Section 13
Comments: Cross Section 5 100 yr flood
Date: 09/08/2006 Time: 5:16:47 p.m.

time step 40 80 hours

Material #: 1	Description:	Hyd K Fn: 1	Vol WC Fn: 1	Ky/Kx Ratio: 0.5	Direction of Kx: 0
Material #: 2	Description:	Hyd K Fn: 2	Vol WC Fn: 2	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 3	Description:	Hyd K Fn: 3	Vol WC Fn: 3	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 4	Description:	Hyd K Fn: 4	Vol WC Fn: 4	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 5	Description:	Hyd K Fn: 5	Vol WC Fn: 5	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 6	Description:	Hyd K Fn: 5	Vol WC Fn: 6	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 7	Description:	Hyd K Fn: 7	Vol WC Fn: 7	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 8	Description:	Hyd K Fn: 8	Vol WC Fn: 8	Ky/Kx Ratio: 0.5	Direction of Kx: 0
Material #: 9	Description:	Hyd K Fn: 9	Vol WC Fn: 9	Ky/Kx Ratio: 1	Direction of Kx: 0

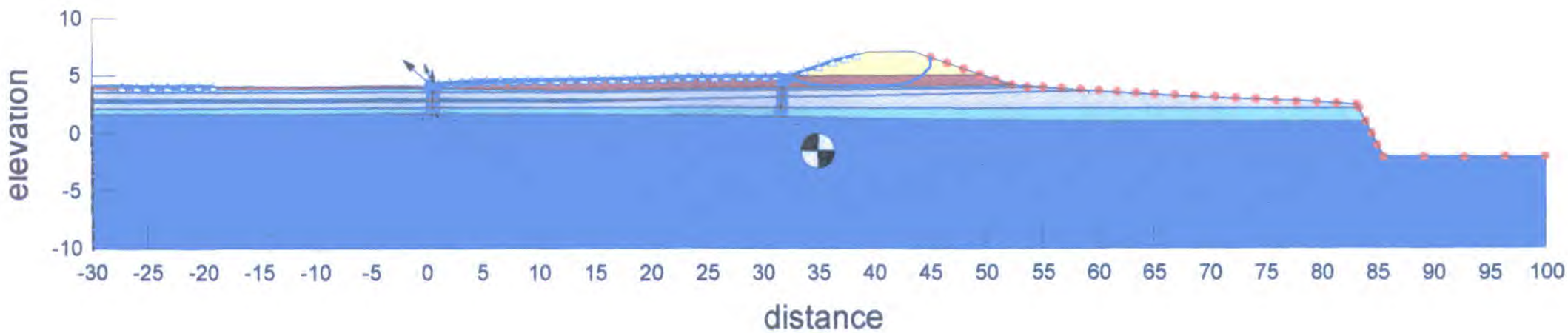


Name: cross section 7 100 yr.gsz
Title: Rangitaiki Stopbanks Section 13
Comments: Cross section 7 100 year flood
Date: 10/08/2006 Time: 6:28:37 p.m.

time step 40 80 hours

pressure relief trenches at toe and edge of road

Material #: 1	Description:	Hyd K Fn: 1	Vol WC Fn: 1	Ky/Kx Ratio: 0.5	Direction of Kx: 0
Material #: 2	Description:	Hyd K Fn: 2	Vol WC Fn: 2	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 3	Description:	Hyd K Fn: 3	Vol WC Fn: 3	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 4	Description:	Hyd K Fn: 4	Vol WC Fn: 4	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 5	Description:	Hyd K Fn: 5	Vol WC Fn: 5	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 6	Description:	Hyd K Fn: 6	Vol WC Fn: 6	Ky/Kx Ratio: 0.5	Direction of Kx: 0
Material #: 7	Description:	Hyd K Fn: 7	Vol WC Fn: 7	Ky/Kx Ratio: 1	Direction of Kx: 0



Name: section 8 100 yr.gsz
Title: Rangitiaki Stopbanks Section 13
Comments: cross section 8 100 yr flood
Date: 10/08/2006 Time: 11:03:58 p.m.

time step 40 -80 hours

toe well

Material #: 1	Description:	Hyd K Fn: 1	Vol WC Fn: 1	Ky/Kx Ratio: 0.5	Direction of Kx: 0
Material #: 2	Description:	Hyd K Fn: 2	Vol WC Fn: 2	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 3	Description:	Hyd K Fn: 3	Vol WC Fn: 3	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 4	Description:	Hyd K Fn: 4	Vol WC Fn: 4	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 5	Description:	Hyd K Fn: 5	Vol WC Fn: 5	Ky/Kx Ratio: 1	Direction of Kx: 0
Material #: 6	Description:	Hyd K Fn: 6	Vol WC Fn: 6	Ky/Kx Ratio: 0.5	Direction of Kx: 0
Material #: 7	Description:	Hyd K Fn: 7	Vol WC Fn: 7	Ky/Kx Ratio: 1	Direction of Kx: 0